Acerca de este libro

Esta es una copia digital de un libro que, durante generaciones, se ha conservado en las estanterías de una biblioteca, hasta que Google ha decidido escanearlo como parte de un proyecto que pretende que sea posible descubrir en línea libros de todo el mundo.

Ha sobrevivido tantos años como para que los derechos de autor hayan expirado y el libro pase a ser de dominio público. El que un libro sea de dominio público significa que nunca ha estado protegido por derechos de autor, o bien que el período legal de estos derechos ya ha expirado. Es posible que una misma obra sea de dominio público en unos países y, sin embargo, no lo sea en otros. Los libros de dominio público son nuestras puertas hacia el pasado, suponen un patrimonio histórico, cultural y de conocimientos que, a menudo, resulta difícil de descubrir.

Todas las anotaciones, marcas y otras señales en los márgenes que estén presentes en el volumen original aparecerán también en este archivo como testimonio del largo viaje que el libro ha recorrido desde el editor hasta la biblioteca y, finalmente, hasta usted.

Normas de uso

Google se enorgullece de poder colaborar con distintas bibliotecas para digitalizar los materiales de dominio público a fin de hacerlos accesibles a todo el mundo. Los libros de dominio público son patrimonio de todos, nosotros somos sus humildes guardianes. No obstante, se trata de un trabajo caro. Por este motivo, y para poder ofrecer este recurso, hemos tomado medidas para evitar que se produzca un abuso por parte de terceros con fines comerciales, y hemos incluido restricciones técnicas sobre las solicitudes automatizadas.

Asimismo, le pedimos que:

+ *Haga un uso exclusivamente no comercial de estos archivos* Hemos diseñado la Búsqueda de libros de Google para el uso de particulares; como tal, le pedimos que utilice estos archivos con fines personales, y no comerciales.
+ *No envíe solicitudes automatizadas* Por favor, no envíe solicitudes automatizadas de ningún tipo al sistema de Google. Si está llevando a cabo una investigación sobre traducción automática, reconocimiento óptico de caracteres u otros campos para los que resulte útil disfrutar de acceso a una gran cantidad de texto, por favor, envíenos un mensaje. Fomentamos el uso de materiales de dominio público con estos propósitos y seguro que podremos ayudarle.
+ *Conserve la atribución* La filigrana de Google que verá en todos los archivos es fundamental para informar a los usuarios sobre este proyecto y ayudarles a encontrar materiales adicionales en la Búsqueda de libros de Google. Por favor, no la elimine.
+ *Manténgase siempre dentro de la legalidad* Sea cual sea el uso que haga de estos materiales, recuerde que es responsable de asegurarse de que todo lo que hace es legal. No dé por sentado que, por el hecho de que una obra se considere de dominio público para los usuarios de los Estados Unidos, lo será también para los usuarios de otros países. La legislación sobre derechos de autor varía de un país a otro, y no podemos facilitar información sobre si está permitido un uso específico de algún libro. Por favor, no suponga que la aparición de un libro en nuestro programa significa que se puede utilizar de igual manera en todo el mundo. La responsabilidad ante la infracción de los derechos de autor puede ser muy grave.

Acerca de la Búsqueda de libros de Google

El objetivo de Google consiste en organizar información procedente de todo el mundo y hacerla accesible y útil de forma universal. El programa de Búsqueda de libros de Google ayuda a los lectores a descubrir los libros de todo el mundo a la vez que ayuda a autores y editores a llegar a nuevas audiencias. Podrá realizar búsquedas en el texto completo de este libro en la web, en la página `http://books.google.com`

This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com

32101 048906257

ST
9280
.123
.29
v.29, pt.2
1908

ANNEX LIB.

Library of

Princeton University.

Elizabeth Foundation.

American Institute of Electrical Engineers

Resolutions in honor of Past-President William Arnold Anthony, adopted by the Board of Directors Friday, June 12, 1908

Whereas: In the death of Professor William Arnold Anthony who departed this life on May 29, 1908, the American Institute of Electrical Engineers has lost one of its earliest members, who throughout the formative years of the Institute served it devotedly as member and as President; and

Whereas: He was a pioneer among electrical engineers and in the cause of technical and scientific education in America; a teacher of rare ability and power to whom a host of pupils, now active in science and its applications owe their first inspiration; and

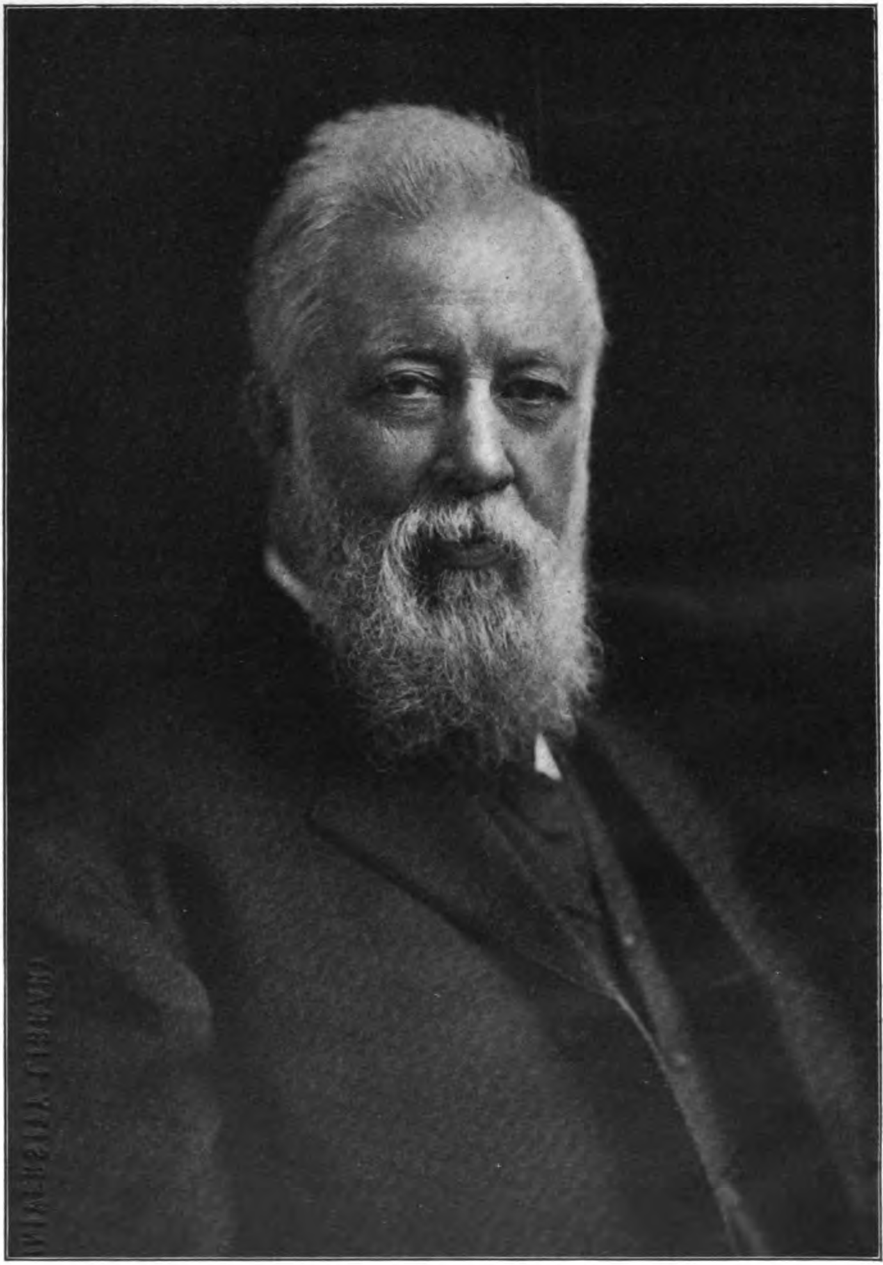
Whereas: His skill as an experimenter, his enthusiasm, insight, and devotion as a man of science commanded universal admiration while his sterling character, single-mindedness, warmness of heart and generosity endeared him to all who knew him;

Be it Resolved: That the American Institute of Electrical Engineers expresses its sense of the great loss which the engineering profession and the cause of science has sustained in his death; and

Be it Further Resolved: That these resolutions be entered in full in the Proceedings of the Institute and that copies be forwarded to the surviving members of his family.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
HENRY G. STOTT,
President.

By order of the Board of Directors.
RALPH W. POPE,
Secretary.



WILLIAM ARNOLD ANTHONY

Past-president of the American Institute of Electrical Engineers, 1890-91
Born November 17, 1835; died May 29, 1908

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly at 33 W. 39th St., New York,
under the supervision of

THE EDITING COMMITTEE
GEORGE F. SEVER, Chairman
PERCY H. THOMAS W. HAND BROWNE, Jr.

GEORGE A. WARDLAW, Editor

Subscription. United States, Mexico and Cuba, $5.00 per year.
All other countries $6.00 per year.
Single copy 50 cents.
Subscriptions must begin with January issue.

Advertisements accepted from reputable concerns at the following net rates:

Space	Less than half year per issue	Half year per issue	One year per issue
1 page	$36.00	$32.00	$30.00
½ page	22.00	18.00	16.00

Additional charges for Preferred Positions.
Professional Cards, special rate of $25.00 per year.

Vol. XXVII **July, 1908** No. 7

Convention Papers and Discussions

OWING to the large number of papers to be presented and discussed at the Atlantic City convention, and the limited time allotted to the professional sessions, it will be necessary to set a time-limit on the presentation of papers and discussions. As most of the 35 papers to be presented have been printed for some time, those not appearing previously being contained in this PROCEEDINGS, all members taking part in the discussion will have had ample time to prepare their remarks before the convention begins. Nor under the conditions will it be necessary for any author to read his paper in full; much time will be saved for discussion by having the authors present their papers in abstract within the time-limit set by the chairman of the Meetings and Papers Committee. The papers to be presented cover, approximately, 17 pages in the March PROCEEDINGS, 164 pages in the May PROCEEDINGS, 350 pages in the June PROCEEDINGS, and 250 pages in the July PROCEEDINGS—a total of 667 pages, not counting the President's address. In accordance with the convention program, these papers are to be presented at eight different sessions from Monday, June 29, to Thursday, July 2. The total time allotted to these eight sessions is 1320 minutes, or approximately 39 minutes for every paper and the complete discussion thereon. Allowing for the time occupied by the Address of Welcome and the President's address, and the intermissions of one kind or another that usually attend meetings of this sort, it is unlikely that more than 30 minutes can be allowed on the average for each paper and the discussion on it. As some of the papers are of more than ordinary interest, it may be necessary in such cases to extend the time-limit for both the paper and discussion; whenever this is found advisable, the extension will be regulated by the presiding officer at the session at which the paper is presented.

The Convention and the Constitution

IN accordance with Section 62 of Article VIII of the Constitution, there shall be held outside of the city of New York, not later than August first, an annual convention of the Institute. At this convention, in addition to the presentation and discussion of professional papers, other matters of immediate interest to the members may be brought up for discussion, and may be referred, with recommendations, by a majority vote, to the Board of Directors. In granting the convention this privilege, however, the Constitution limits the power of a convention by stating, further, that no convention shall have the privilege of transacting any business that may affect either the policy or the organization of the Institute.

(RECAP) 561706 Digitized by Google

Announcement of the Twenty-fifth Annual Convention Atlantic City, N. J., June 29 to July 2, 1908

The Institute Headquarters during the convention will be at the Hotel Traymore. Upon arrival in Atlantic City, please register at the INSTITUTE headquarters and obtain an identification badge. The convention sessions will be held in the Hotel Traymore.

Convention Committee, 1908

W. C. L. EGLIN, Chairman, 1000 Chestnut St., Philadelphia, Pa.

CHARLES DAY, 608 Chestnut St., Philadelphia, Pa.

J. J. GIBSON, 705 Land Title Building, Philadelphia, Pa.

NATHAN HAYWARD, Bell Telephone Co., Philadelphia, Pa.

H. F. SANVILLE, 1122 North American Building, Philadelphia, Pa.

PAUL SPENCER, Broad and Arch Sts., Philadelphia, Pa.

PROGRAM†

Monday, June 29

MORNING SESSION—11 A.M. TO 12.30 P.M.

1. Address of Welcome.
2. President's Address: by HENRY G. STOTT.
3. C. M. GODDARD, "Electricity as Viewed by the Insurance Engineer. Should the A.I.E.E. Interest Itself in Fire Protection?"
4. F. G. BAUM, "Water Power Development in the National Forests. A Suggested Government Policy."

AFTERNOON SESSION—2 P.M. TO 5 P.M.

5. W. LEE CAMPBELL, "A Study of Multioffice Automatic Switchboard Telephone Systems."
6. R. A. FESSENDEN, "Wireless Telephony."
7. A. E. KENNELLY and S. E. WHITING, "The Measurement of Rotary Speeds of Dynamo Machines by the Stroboscopic Fork."
8. CHAS. E. WADDELL, "Notes on the Electric Heating Plant of the Biltmore Estate."

Tuesday, June 30

MORNING SESSION—9.30 A.M. TO 12.30 P.M.

9. E. E. F. CREIGHTON, "Measurements of Lightning, Aluminum Lightning-arresters, Earth Resistances, Cement Resistances, and Kindred Tests."
10. ERNST J. BERG, "Tests with Arcing Grounds and Connections."
11. AUSTIN BURT, "Three-phase Power Factor."
12. PERCY H. THOMAS. "Critical Study of Lightning Records on Taylor's Falls Transmission Line."
13. J. W. FRASER, "Engineering Features of the Southern Power Company's System."

EVENING SESSION—8 P.M. TO 10.30 P.M.

14. RALPH D. MERSHON, "High-Voltage Experiments at Niagara."
15. D. R. SCHOLES, "Fundamental Considerations Governing the Design of Transmission Line Structures."
16. C. E. SKINNER, "The Testing of High-Voltage Line Insulators."

Wednesday, July 1

MORNING SESSION—9.30 A.M. TO 12.30 P.M.

17. COMFORT A. ADAMS, "Voltage Ratio in Synchronous Converters, with Special Reference to the Split-Pole Converter."
18. J. LESTER WOODBRIDGE, "Application of Storage-Batteries to Regulation of Alternating-Current Systems."
19. B. A. BEHREND, "A New Large Generator for Niagara Falls."
20. W. L. WATERS, "Modern Developments in Single-Phase Generators."
21. JENS BACHE-WIIG, "Application of Fractional-Pitch Windings to Alternating-Current Generators."

---

†The sequence of papers and the dates assigned are subject to change.

22. J. R. **Bibbins**, "Double-Deck Steam Turbine Power Plants."
23. J. R. **Bibbins**, "Working Results from Gas-Electric Power Plant. Report of 30 Day Test on Service Plant, Richmond Works, American Locomotive Company."

AFTERNOON SESSION—2 P.M. TO 5 P.M.

24. J. B. **Whitehead**, "From Steam to Electricity on a Single-Track Road."
25. H. C. **Specht**, "Induction Motors for Multispeed Service with Particular Reference to Cascade Operation."
26. **Gerard B. Werner**, "The Determination of the Economic Location of Sub-Stations in Electric Railways."
27. S. B. **Fortenbaugh**, "Conductor Rail Measurements."

Thursday, July 2

MORNING SESSION—9.30 A.M. TO 12.30 P.M.

28. C. P. **Steinmetz**, "The General Equations of the Electric Circuit."
29. C. P. **Steinmetz**, "Primary Standard of Light."
30. **Carl Hering**, "An Imperfection in the Usual Statement of the Fundamental Law of Electromagnetic Induction." (With discussions by letter).
31. R. E. **Hellmund**, "Graphical Treatment of the Rotating Field."
32. **Harold Pender**, "A Minimum-Work Method for the Solution of Alternating-Current Problems."
33. **Carl J. Fechheimer**, "The Relative Proportions of Copper and Iron in Alternators."

AFTERNOON SESSION—2 P.M. TO 5 P.M.

34. M. W. **Alexander**, "A New Method of Training Engineers."
35. D. B. **Rushmore**, "The Relation of the Manufacturing Company to the Technical Graduate."
36. B. A. **Behrend**, "The Relation of the Manufacturing Company to the Technical Graduate."

Entertainment

The local committee has arranged the following events:

A reception followed by a dance will be given at the Hotel Traymore on Monday evening, June 29. All members and guests in attendance at the convention are invited.

Tickets of admission to the Steel Pier, and possibly some of the other piers, will be provided for the visiting ladies. Informal sailing parties on the fleet of yachts which leave from the inlet will be arranged. Tickets may be obtained at the Institute headquarters in the Hotel Traymore.

Members who desire to play golf will be accorded the privileges of the Atlantic City Golf Club's Links. Cards may be obtained on application at the Institute headquarters.

A Tea will be given at the Golf Club on Tuesday afternoon, June 30.

The bathing at Atlantic City is so excellent and the other attractions and amusements are so varied and extensive that it has been deemed inadvisable to make any arrangements for entertainment other than those mentioned above.

Transportation Arrangements

General. Every person who intends to attend the Convention should make his own arrangements for transportation.

The concession of one-third fare for the return trip on the certificate plan which has been obtained in previous years for members and guests attending our conventions has been granted by only three of the passenger associations this year, viz., New England, Trunk Line, and Eastern Canadian, Passenger Associations. The territory controlled by these associations is defined on page 4.

In reply to applications for concession and rates, the Central, Western, and Southeastern Passenger Associations and the Southwestern Excursion Bureau have directed attention to their summer tourist rates to Atlantic City, beginning

June 1 and ending September 30. Members and guests from territory controlled by these associations should apply to their local ticket agents for further information.

Territory Controlled by Passenger Associations

Trunk Line Association. All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware, and Maryland, also the northern portions of Virginia and West Virginia. [Notice has been received that the New York, Ontario and Western, and the Chesapeake & Ohio, Railways will not grant the concession of one-third fare for the return trip.]

New England Passenger Association. Territory east of New York State.

Eastern Canadian Passenger Association. Territory in Canada east of and including Port Arthur, Sault Ste. Marie, and St. Clair and Detroit Rivers.

Central Passenger Association. Territory west of Buffalo, Pittsburg, Wheeling, Parkersburg, and Huntington to and including Chicago and St. Louis, and north of the Ohio River, including Cincinnati, Louisville and Cairo.

Southeastern Passenger Association. Territory south of the Ohio and Potomac and east of the Mississippi Rivers.

Western Passenger Association. Territory west of Chicago, Peoria, and St. Louis to and including Denver, Colo., and Cheyenne, Wyoming.

Southwestern Excursion Bureau. Territory southwest of St. Louis, including Texas, Arkansas, Oklahoma, Missouri (south of Missouri River) and Louisiana (west of Mississippi River).

One and One-third Fare for the Round Trip

Tickets will be issued at all the principal stations and ticket offices of the New England, the Trunk Line, and the Eastern Canadian Passenger Associations to members and guests on the certificate plan, which allows the holders of such certificates to purchase tickets from Atlantic City to original starting point via the same route as the going ticket, at one-third the regular fare, *provided there are at least* 100 *certificates presented.*

Tickets at full fare for the going journey may be obtained three days exclusive of Sundays prior to the meeting, and also during the first three days

Atlantic City Hotel Rates.

Hotel	Guest capacity	Proprietor or Manager	Plan	Rates
The Boardwalk.				
TRAYMORE (*Convention Headquarters*)	600	D. S. White, Pres. C. O. Marquette, Mgr.	American	Per day, $4 up; week, $21 up.
Brighton	300	F. W. Hensley & Son	American	On application.
Chalfonte	600	The Leeds Co.	American	Per day, $4 up.
Dennis	600	Walter J. Buzby	American	Per day, $3.50 to $6; week, $21 to $35.
Haddon Hall	450	Leeds & Lippincott	American	On application.
Marlborough	1100	Josiah White & Sons	American	Per day, $4 to $10; week, $25 to $50.
-Blenheim			European	Per day, $2 to $8; week. $13 to $33.
St. Charles	300	Newlin Haines	American	Per day, $3 to $7; week, $17.50 to $50.
Shelburne	300	Jacob Weikel	European	Per day, $1.50 up.
Windsor	200	G. Jason Waters	American	Per day, $3 to $6; week, $18 to $40.
			European	Per day, $2 to $6.
Vermont Avenue.				
Earl-Mar Hall	300	L. J. Brown	American	Per day, $2 to $5; week, $10 to $17.50.
Vermont	150	M. E. Geiger	American	Per day, $1 to $3; week, $7 to $15.
Connecticut Avenue				
Galen Hall	350	Galen Hall Co.	American	On application.
St. Charles Place.				
Loraine	200	Charles E. Wagner	American	Per day, $3 up; week, $15 to $30.
Raleigh	400	Henry J. Dynes	American	Per day, $2.50 to $4; week, $15 to $25.
Virginia Avenue.				
Ponce de Leon	300	A. B. Grindrod	American	Per day, $2 up; week, $12 up.
			European	Per day, $1.50 up; week, $7.00 up.
Berkshire Inn	300	J. O. & J. E. Dickinson	American	Per day, $2 to $5; week, $9 to $18.

of the meeting. The schedule dates of the Convention are from June 29 to July 3; consequently, tickets may be obtained not earlier than June 25, nor later than July 1. The going tickets are good on any train. The reduced rate return tickets are not good on some limited trains.

Be sure to make application for your certificate when purchasing your ticket to Atlantic City. Should certificates not be available at the office where application is made, a ticket should be purchased to the nearest station where certificates are issued and a ticket to Atlantic City, together with the certificate obtained there. *Do not make the mistake of asking for a receipt instead of a certificate.*

It is advisable to ascertain in advance whether the ticket agent from whom you purchase your ticket has the necessary instructions. Applications for tickets and certificates should be made a reasonable time before train is scheduled to depart, as it requires a few minutes for the agent to fill out the certificates.

Immediately after your arrival at Atlantic City, present your ticket to be viséed at the Institute headquarters in the Hotel Traymore. A fee of twenty-five cents will be charged by the railroad agent for each certificate endorsed by him.

It should be noted that members must return to the starting point, otherwise there will be no reduction in the fare. No claim for refund will be entertained by the railroad companies on account of holders of tickets returning to starting point before the requisite number of 100 certificates is in the hands of the special agent of the railways. Return tickets at the reduced fare are valid for three entire days after the convention adjourns, not including Sundays; that is, on trains leaving Atlantic City before midnight on July 7. These return tickets are in all cases limited to continuous passage. Neither certificates nor return tickets are transferable, and the Institute has agreed to redeem at full rates any return tickets that are found to have been transferred.

Hotel Rates

Each member should arrange for his own hotel accommodations; early application is desirable.

The list on opposite page contains the names, addresses, and rates of a few of the well-known hotels in Atlantic City; the number of hotels is so large that lack of space prevents printing a complete list here.

Report of the Committee of Tellers on Election of Officers

MAY 8, 1908.

To the President of the American Institute of Electrical Engineers:

DEAR SIR: This committee has carefully canvassed the ballots cast for officers for the year 1908-1909. The result is as follows:

Total number of envelopes said to contain ballots, received from Secretary		2,102
Rejected on account of bearing no identifying name on outer envelope, according to Article VI, Section 33 of the Constitution	14	
Rejected on account of voter being in arrears for dues on May 1, 1908, as provided in the Constitution and By-laws	128	
Rejected on account of ballot not being enclosed in inner envelope, or on account of inner envelope bearing an identifying name, according to Article VI, Section 33 of the Constitution	37	
Rejected on account of having reached the Secretary's office after May 1, according to Article VI, Section 33 of the Constitution	19	
		198
Leaving as valid ballots		1,904

These valid ballots were counted, and the result is shown below:

For President:

L. A. Ferguson	1,766	
R. D. Mershon	99	
L. B. Stillwell	20	
A. H. Armstrong	15	
Blank	4	
		1,904

For Vice-presidents:		
C. C. Chesney	1.868	
Calvert Townley	1,827	
B. Gherardi	1,754	
C. L. Edgar	79	
E. J. Berg	66	
P. Junkersfeld	22	
Ralph D. Mershon	20	
J. J. Carty	19	
A. S. Langsdorf	19	
F. S. Hunting	1	
L. B. Stillwell	1	
Blank	36	
		5,712
For Managers:		
D. B. Rushmore	1,869	
H. E. Clifford	1,857	
C. W. Stone	1,807	
W. G. Carlton	1,690	
H. B. Smith	103	
J. G. Wray	48	
A. W. Berresford	47	
N. W. Storer	47	
F. S. Hunting	33	
W. S. Murray	25	
W. S. Rugg	25	
H. W. Fisher	23	
E. J. Berg	1	
Blank	41	
		7,616
For Treasurer:		
George A. Hamilton	1,901	
Blank	3	
		1,904
For Secretary:		
Ralph W. Pope	1,900	
Blank	4	
		1,904

Respectfully submitted,
F. L. Hutchinson,
Chairman.
Leigh S. Keith,
Geo. I. Rhodes,
Walter I. Tamlyn.
Committee of Tellers.

New Committees

The following two committees have recently been appointed by President Stott:

Committee on Revision of the By-Laws

Calvert Townley, *Chairman.*
C. C. Chesney.
Percy H. Thomas.

Committee on Intermediate Grade of Membership

Chas. F. Scott, *Chairman.*
K. L. Aitken.
William McClellan.
George F. Sever.
Paul Spencer.

Sections and Branches

Kansas University Branch

A meeting was held May 7, 1908, Professor M. E. Rice presiding, with an attendance of 22. The executive committee was instructed to prepare a special program and furnish refreshments for the last regular meeting of the year on May 21. T. T. Hambleton discussed difficulties encountered in his senior thesis work on " Determination of Iron Losses " and Professor Rice then led the discussion on the Institute paper, " The Engineer's Activity in Public Affairs ", which appeared in the April Proceedings. A brief outline of the paper was given by Professor Rice, and a general discussion followed.

Purdue Branch

At a meeting of the Purdue Branch on March 16, 1908, Professor Plumb, before a large audience, gave a popular lecture on high-frequency currents and their behavior. The lecture was profusely illustrated with simple and interesting experiments.

A meeting was held in the electrical building, on May 12, 1908, R. B. Webb, presiding, with an attendance of 45.

" Electrical Engineering Education ", by Chas. P. Steinmetz, and " The Best Engineering Education ", by C. F. Scott; formed the nucleus of the evening's discussion.

Dean Benjamin stated his own objections to the tendency to teach too many things without undue specialization in any. He pleaded for attention to fundamentals, and advised that the college work should include the particular training unobtainable outside of the school room. He spoke of the low pay of the teaching profession contrasted with equal ability in commercial pursuits. He exhibited some interesting curves derived from a well known engineering school showing the increase in the number of instructors and assistants necessary to keep pace with the rapidly increasing enrolment.

Professor Harding spoke of the recent attention engineering education has been accorded by engineers and professors in Institute discussions. The professor advised the engineer to think rather than to memorize. He urged close attention between theory and practice and observed the importance of culture subjects to the engineer. He described six years as an ideal technical college course, the first four years to consist largely of culture work leading the bachelor degree, the last two to be strictly devoted to engineering studies, culminating in the degree of engineer. A five year course should be divided similarly into three and two years of culture and technical work respectively. A course similar to this is now in effect at Wisconsin.

MEXICO SECTION

A meeting was held on April 10, Chairman R. F. Hayward presiding, with an attendance of 35, when William B. Hale read the paper entitled "Lightning Rods and Grounded Cables as a Means of Protecting Transmission Lines Against Lightning", an Institute paper by Norman Rowe, presented at the twenty-fourth annual convention, Niagara Falls, June 26, 1907. The reading of the paper was followed by a lively discussion in which Messrs. Foley, Herrman, Parsons, Leonarz, Cornick, Reynolds, Nims, and Hayward participated.

A meeting was held in Sylvain's restaurant on May 15, Chairman R. F. Hayward presiding, with an attendance of 40, when Mr. Leonarz read a paper on "Losses in Hydraulic Plant and Transmission System and Their Values."

One point on which some little discussion arose was that of "Distribution", and Mr. Leonarz was requested to submit a paper on "Losses in Local Distribution and Their Values". In reference to efficiency of apparatus, lines, etc., some interesting remarks were called forth, and Mr. Hayward incidentally suggested in connection with transmission lines that existing lines might be made to appreciate in value instead of standing on a depreciating basis. Also he suggested consideration of the actual value of power at headworks in comparison with estimated values.

Mr. Lobo said it would be possible to cut down the depreciation figures shown by transferring some to operation; that he considered the percentage loss on transformers should be ten instead of five: and that on the sub-station, five per cent. is far too low. He asked if the percentages given for loss on power house equipment, transformers, etc., included expenditures for repairs, and whether office charges had been calculated into these percentages.

UNIVERSITY OF TEXAS BRANCH

Meetings of the University of Texas Branch of the Institute were held on May 15 and 22.

The program of the first meeting included a general report by the chariman and secretary, of a meeting of the Southwestern Electrical & Gas Association which they attended at El Paso on May 7, 8, and 9. The report included a review of the work of the American Street & Interurban Railway Association by B. V. Swenson, who was present at the El Paso meeting. A paper dealing with "A Large Irrigation System Near San Benito, Texas", was presented by a member of the Branch, and called forth much interesting discussion. A review of the "Electrical Haulage of Canal Boats" and the "Question Box" completed the evening session.

A special paper was presented at the second meeting on May 22 on the subject of "Wood Preserving" in which the fundamental principles of decay of wood, and proper means for preventing such decay, were thoroughly discussed. The different preparations in use for wood preserving were considered, and also the results thus far obtained by the Santa Fe Railway in its experiment in connection with the preserving of ties on a very large scale near Pelican, Texas.

The " Question Box ", which is intended to be a feature at every meeting, covered the discussion of a number of questions, an important one of which was " Comparative first cost and operating expense of various forms of prime movers, including steam, city gas, oil, and suction producer units."

URBANA SECTION

A meeting was held in the electrical engineering laboratory on April 29, J. M. Bryant presiding, with an attendance of 35. Professor E. H. Waldo delivered an address on forest preservation illustrated by a series of lantern slides, and the subject was discussed by Professor Brooks, Mr. Bryant, Professor Hottes, and others.

Associates Elected and Transferred

At a special meeting of the Board of Directors at 33 West 39th Street, New York on Friday June 12, 1908, at 3:30 p.m. The following 134 Associates were elected:

ADAMS, JAMES LUCIAN, JR., Engineer in charge, Power Plant and Conduit Construction Consumers' Electric Co.; res., 1334 Whittier Ave., Springfield, Ill.

ALLING, ALBERT L., Draftsman, Assistant Estimator, Lord Electric Co., 213 West 40th St., res.; 617 W. 152d St., New York City.

ATWOOD, CARLTON ELLIOT, Electrical Engineer, with J. K. Robinson, Iquique, Chile, S. A.

BARNERT, MEYER, Steam Turbine Erector, General Electric Co., Empire Bldg., Atlanta, Ga.

BARTLETT, GEORGE WILLIAM, Superintendent, Chicago and Oak Park Elevated Railway Co., 1922 Marshall St., Chicago; res., Hotel Plaza, Oak Park, Ill.

BENEDICT, ALLAN B., Draftsman, Goodman Mfg. Co., 4834 So. Halsted St.; res., 321 E. 57th St., Chicago, Ill.

BERRY, MORPHY EDISON, Acting Chief Inspector, Western Electric Co., Hawthorn; res., 330 S. Central Ave., Austin, Ill.

BOYD, ALEXANDER H., Salesman, Fort Wayne Electric Works, Fort Wayne, Ind.

BOYLES, ALBERT EDWIN, Superintendent Maintenance, Independent Telephone Co., Seattle, Wash.

BRACH, LEON ST. CLAIR, Eastern Manager, McClintock Mfg. Co., 136 Liberty St.; res., 201 W. 121st St., New York City.

BRACKETT, ELMER EUGENE, Instructor Electrical Engineering, University of Pennsylvania; res., 6020 Delancey St., Philadelphia, Pa.

BRODNER, ELMER ATHERTON, General Superintendent and Engineer, Grays Harbor Railway and Light Co., Aberdeen, Wash.

BUCHECKER, ALBERT ISREAL, Student, University of Wisconsin; res., 703 State St., Madison, Wis.

CARPENTER, DAN ELLSWORTH, Technical Writer, International Textbook Co., East McKeesport; res., Scranton, Pa.

CHASE, HARRY MARSHALL, Chief Electrician, Choctaw R.R. and Light Co., McAlester, Okla.; res., Green Bay, Wis.

CLARK, CURTIS WILSON, Superintendent and Electrical and Mechanical Engineer, Marion, Bluffton and Eastern Traction Co., 510 W. Wiley Ave., Bluffton, Ind.

COAKLEY, MORGAN TEW, Engineering Apprentice, Westinghouse Electric and Mfg. Co., 831 E. Hutchinson Ave., Pittsburg, Pa.

COBB, STEPHEN PRENTIS, Rochester Railway and Light Co., 34 Clinton Ave., N., Rochester, N. Y.

COFFIN, ROBERT CLEVELAND, General Electrical and Office Employee, Standard Oil Co. of N. Y.; res., 278 W. 120th St., New York City.

CONNOLLY, STEPHEN JOSEPH, Chief Engineer of Mill Department, Portland Gold Mining Co., 1128 Colorado Ave., Colorado Springs, Colo.

Cook, Cleo Brenton, Sales Engineer, Allis-Chalmers Co., 303 Michigan Bldg., Toledo, O.

Correll, James A., Tutor, Electrical Engineering, University of Texas, Austin, Texas.

Cox, Herbert Hughes, Operator, San Bernardino Gas and Electrical Co., San Bernardino, Cal.

Cranston, James Albert, Manager Portland Office, General Electric Co., Portland, Ore.

Crighton, William Harvey, Chief Draftsman, Fort Wayne Electric Works, 705 W. Berry St., Fort Wayne, Ind.

Cross, Alfred Singlehurst, Electrical Engineer, Allgemeine Elek. Gesellschaft, Berlin, Ger.; res., 15 Fulwood Park, Liverpool, Eng.

Davis, Maynard Reed, Erecting Engineer, Westinghouse Electric and Mfg. Co., 429 17th St., Denver, Colo.

D'Espies, Arthur, Assistant to Chief Engineer, C. & C. Electric Co.; res., 253 Morris Ave., Elizabeth, N. J.

Ditzler, Guy Elon, Designing Electrical Engineer, Western Electric Co., Hawthorn; res., 720 Woodbine Ave., Oak Park, Ill.

Dodds, William Black, Cadet Engineer, Denver Gas and Electric Co.; res., 500 14th St., Denver, Colo.

Dubois, Edward, Technician and Engineer, Fort Wayne Electric Works, 1839 Broadway, Fort Wayne, Ind.

Dunlop, Robert J., Technical Salesman, Canadian Westinghouse Co.; res., 27 Montague Pl., Toronto, Ont.

Elsdon-Dew, William, Mechanical and Electrical Engineer, Transvaal Gold Mining Est. Ltd.; res., Sunnyside, Pilgrims Rest, Transvaal.

Faber, Paul, Draftsman, Sanitary District of Chicago, 1808 Arlington Pl., Chicago, Ill.

Filer, Burt Kishlan, General Foreman, Installation Department, Western Electric Co.; res., 783 Clifton Park Ave., Chicago, Ill.

Fox, Bertram Douglas, Electrical Assistant, Sir Douglas Fox and Partners; res., 56 Moorgate St., London, Eng.

Frazier, Paul Douglas, Electrical Construction man, General Electric Co.; res., 1329 Oxford St., Berkeley, Cal.

French, Edwin Linton, Electrical Superintendent, Union Carbide Co., Saulte Ste Marie, Mich.

Gilman, Edward F., Electrician, Wood Worsted Co., 39 Avon St., Lawrence, Mass.

Goettsch, Julius, Sales Engineer, Western Electric Co.; res., 328 No. Grove Ave., Oak Park, Ill.

Gooding, Ralph Othniel, Salesman, Western Electric Co.; res., Riverside, Ill.

Gould, Lawrence E., Editor in Chief Electric Railway Review, 160 Harrison St.; res., 5429 Jefferson Ave., Chicago, Ill.

Graef, Walter Herman, Electrical Engineer, with J. K. Robinson, Iquique, Chile, S. A.

Grandstoff, Ed Granger, Chief Instructor New York Electrical Trades School, 39 W. 17th St.; res., 225 W. 133d St., New York City.

Greenleaf, Wilmot Lockwood, Superintendent, Penobscot Bay Electric Co., Bucksport, Me.

Greiff, Victor, Assistant Electrical Engineering Department, Columbia University; res., 166 W. 79th St., New York City.

Grover, Earl Waldo, District Operator, Commonwealth Edison Co., 6945 Stewart Ave., Chicago, Ill.

Hamilton, Chester Brown, Jr., Designer on Crude Oil Engines, Johnston Oil Engine Co., res.; 43 Madison Ave., Toronto, Ont.

Hamilton, Frank Edverse, Sales Engineer, Allis-Chalmers Co., 471 Marshall St., Milwaukee, Wis.

Hamilton, William Garfield, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg; res., 811 Franklin Ave., Wilkinsburg, Pa.

Harcourt, Clayton J., Electrical Engineer, New York Telephone Co.; res., 3 So. Elliott Pl., Brooklyn, N. Y.

Harraden, Walter Leroy, Expert, General Electric Co., Union Trust Bldg., San Francisco, Cal.

Haskin, Lawrence Sprague, Erecting Engineer, Westinghouse Electric and Mfg. Co., Waterford, Conn.

Hazell, Henry William, Foreman Electrician, C. H. Walker and Co., Ltd., Carioca 711, Rio de Janeiro, Brazil.

Healy, Francis Joseph, Public Service Corporation of N. J., 207 Market St.; res., 25 13th Ave., Newark, N. J.

Henrekson, John Waldemar, Assistant Engineer in charge Drafting Department, Goodman Mfg. Co., 48th Place and Halsted St.; res., 5947 Emerald Ave., Chicago, Ill.

Hobbs, Caleb, General Electric Co.; res., 20 Swan St., Schenectady, N. Y.

Hollister, John Murray, Western Electric Co., Hawthorn; res., 4133 Perry Ave., Chicago, Ill.

Hungerford, Oliver Townsend, General Manager, Dielectric Co. of America, Belleville, N. J.

Hunter, James Cadwallader, Capt. P. W. Dept., Resident Engineer, Jhelum Power Installation; Rampur-Kashmir, India.

Hurst, George Edward, Draughtsman, Pennsylvania Railroad Co., Altoona, Pa.

Kemp, Francis Leroy, Assistant Foreman Testing Department, General Electric Co.; res., 18 Eagle St., Schenectady, N. Y.

Kenney, Francis MacCullough, General Foreman, Switchboard Instruction Department, Western Electric Co.; res., 309 Oakland Ave., Pittsburg, Pa.

Kephart, Edwin Murray, Electrical Engineer, Stone and Webster, 147 Milk St., Boston, Mass.; res., 21 Eagle St., Schenectady, N. Y.

King, Lloyd Everette, Engineer on Power Apparatus, Western Electric Co., Chicago; res., Berwyn, Ill.

Kingsbury, Albert, Westinghouse Electric and Mfg. Co.; res., 219 Stratford Ave., Pittsburg, Pa.

Kolb, Frederick Valentine, Chief Electrical Draftsman, Fore River Shipbuilding Co., Quincy; res., 24 Clive St., Atlantic, Mass.

Lewis, Howard Ormsbee, Graduate Student, Worcester Polytechnic Institute; res., 2 State St., Worcester, Mass.

Lozier, Chester Albert, Draftsman, Public Service Corporation of N. J.; res., 23 Cottage St., Newark, N. J.

Lucas, Albert Garfield, Meter Expert, Fort Wayne Electric Works; res., 706 W. Berry St., Fort Wayne, Ind.

Lunn, Guy W., Chief Electrician, Fisk St. Station, Commonwealth Edison Co., 22d and Fisk Sts.; res., 1710 W. 15th St., Chicago, Ill.

Mack, Frank Wesley, Manager, Storm Lake Electric Light and Power Co., Storm Lake, Iowa.

Marca-Romero, Manuel A., Electrical Engineer, Las Empresas Electricas Associadas, Lima, Peru.

Markle, Alvan, President, Wilkes-Barre and Hazelton Railway Co., Hazelton, Pa.

McCann, William Ray, Mechanical Draftsman, Isthmian Canal Commission, Culebra, Canal Zone, Panama.

Mellinger, Edward A., Assistant Engineer, Automatic Electric Co., Chicago, Ill.

Migneault, Harry M., Supply Salesman, General Electric Co., Cincinnati, O.; res., No. Milwaukee, Wis.

Mini, Joseph, Jr., Electrical Construction Foreman, Cal. Gas and Electric Corporation, Los Gatos; res., Deer Creek, P. H. Nevada City, Cal.

Mitchell, William Galbraithe, British Thomson Houston Co., Ltd.; res., Kilmeny Dundruch Road, Rugby, Eng.

Monges, Richard Fenner, Assistant Electrical Engineer, General Electric Co., San Francisco, Cal.

MONTAGUE, HUBERT HOWARD, General Salesman, Western Electric Co., Chicago; res., 328 N. Grove Ave., Oak Park, Ill.

MOORE, JOHN ELY, Engineer, Arnold Co., 181 La Salle St.; res., 3298 Beacon St., Chicago, Ill.

MOORE, ORLO SAFFORD, Designing Electrical Engineer, Western Electric Co., Chicago; res., 5912 Randolph St., Austin, Ill.

MORRIS, ROBERT, Inspector, N. Y. C. & H. R. R.R. Co., Room 2, Grand Central Station, New York; res., 276 Riverside Ave., Yonkers, N. Y.

MOTTINGER, BYRON THOMAS, Electrical Engineer, Peerless Electric Co., 309 Porter Ave., Warren, O.

MOWER, GEORGE L., Assistant Engineer Transformer Department, General Electric Co.; res., 70 Maplewood Ave., Pittsfield, Mass.

MUDGETT, ORLO DUDLEY, Erecting Engineer, Westinghouse Electric and Mfg. Co., 716 Board of Trade Bldg.; res., 26 Union Park, Boston, Mass.

NELSON, FRED LEONARD, Assistant Electrical Engineer, Pacific Light and Power Co., 254 So. Los Angeles St , Los Angeles; res., 221 So. Marengo Ave., Pasadena, Cal.

NICKERSON, CHARLES WILLIS, JR., Inspector of Construction, Westchester Lighting Co., Mt. Vernon; res., New Rochelle, N. Y.

NOYES, ROBERT EDGAR, Instructor in Electrical Engineering, Case School of Applied Science, Cleveland, O.

PEARSON, JOHN WINTHROP, Foreman Testing Department, Western Electric Co., Chicago; res., 1298 Wilcox Ave., Chicago, Ill.

PEIRCE, ROBERT FRENCH, Manager, Menevallal Co., 839 Monadnock Bldg. res., 1206 Ainslee St., Chicago, Ill.

PENARD, THOMAS EDWARD, Electrical Engineer, Edison Electric Illuminating Co. of Boston, 39 Boylston St., Boston; 32 Irving St., Everett, Mass.

PRICE, EDWIN DELAPLAINE, Assistant Department Manager, Western Electric Co., Chicago; res., 616 So. 15th Ave., Maywood, Ill.

RABELLO, CESAR, Guinle and Co., Rio de Janeiro, Brazil.

REDPATH, ROBERT MCADAM, Construction Engineer, Salmon River Power Co., Sawyer Bar, Cal.

RIBEIRO, MARIO, Guinle and Co., Rio de Janeiro, Brazil.

RICE, DON MARTIN, Mechanical Engineer, Lehigh Coal and Navigation Co., Mauch Chunk, Pa.

RICE, LOUIS ALBERT, Designing Engineer, Niagara Falls Hydraulic Power and Mfg. Co.; res., 460 8th St., Niagara Falls, N. Y.

RICH, EDWARD PRICKETT, Mechanical and Electrical Engineer and Member of Co., Pierce Richardson and Neiler, 1409 Manhattan Bldg; res., 3254 So. Park Ave., Chicago, Ill.

ROUNDS, JOHN E., Engineering Apprentice, Denver Sales Office, Westinghouse Electric and Mfg. Co; res. 3018 East Colfax St., Denver, Colo.

ROWNEY, WILLIAM H., Engineer in Switchboard Department, Western Electric Co.; res., 302 So. Eighth Ave., La Grange, Ill.

RUSH, CHARLES GOETHE, Engineer in charge of Construction, Sanitary District of Chicago; res., 5404 Indiana Ave., Chiacgo, Ill.

SCHMIDT, FREDERICK EDGAR, Instructor Electrical Engineering, Mechanics Institute, 140 W. 23d St., New York; res., 31 N. Bleeker St., Mt. Vernon, N. Y.

SCHROEDER, HENRY, Salesman, General Electric Co., Harrison, N. J.; res., 155 Maple Ave., Flushing, L. I., N. Y.

SHULZ, WILLIAM, Sales Department, Bristol Co., Waterbury; res., Naugatuck, Conn.

SCHUPP, PETER V., Assistant in Electrical Engineering, Mississippi Agricultural and Mechanical College, Agricultural College, Miss.

SERRELL, ALFRED THOMAS, Foreman Bond Inspector Test, Department, N. Y. C. & H. R. R.R.; res., 317 Riverside Ave., Yonkers, N. Y.

Sherman, George A., General Stock Clerk, Western Electric Co., 642 Folsom St.; San Francisco; res., 1533 Walnut St., Berkeley, Cal.

Simmon, Karl Albert, Engineer, Westinghouse Electric and Mfg. Co., Pittsburg; res., 401 Colonial Bldg., Wilkinsburg, Pa.

Sims, George Frederick William, Tester Dynamo Test., Westinghouse Electric and Mfg. Co., Pittsburg; res., 2 Colonial Bldg., Wilkinsburg, Pa.

Smith, Edward William Peter, Student, Colorado College; res., 930 N. Weber St., Colorado Springs, Colo.

Smith, Julian Cassius, Engineer in charge, Panama Railway Co., La Boca, Canal Zone, Panama.

Smith, Peter J., Commonwealth Edison Co., 76 Market St.; res., 45 Seminary Ave., Chicago, Ill.

Southerland, Frederick Jewell, General Superintendent, Monterey County Gas and Electric Co., Monterey, Cal.

Stivers, John O., President and General Manager, J. O. Stivers Electric Co., Denver, Colo.

Stouffer, Christian S., Accounting Department, Westinghouse Electric and Mfg. Co., Pittsburg; res., 121 Edgewood Ave., Edgewood Park, Pa.

Tillman, Richard Henry, Member Engineering Staff, Rochester Railway and Light Co., 34 Clinton Ave. N.; res., 56 Charlotte St., Rochester, N. Y.

Tounsend, George P., Salesman, General Electric Co., Chicago, Ill.

Trobee, Harry C., General Electric Co.; res., 574 3d St., San Francisco, Cal.

Walden, Albert Edward, Chief Engineer, Baltimore County Water and Electric Co., Baltimore, Md.

Weil, Edgar Edward, Partner, Enterprise Electrical Co.; res., 413 Baronne St., New Orleans, La.

Weiss, Tobias, Salesman, National Automatic Fire Alarm Co. of La.; res., 614 Graner St., New Orleans, La.

Weymann, Charles Martin, Foreman, S. F. Repair Shop, General Electric Co.; res., 124 Fillmore St., San Francisco, Cal.

Whalen, James M., Manager of Machinery Department, Northwestern Electric Equipment Co.; res., 185 E. 4th St., St. Paul, Minn.

Wier, Joel Alexander, Engineer and Electrician, Saltillito Mining and Milling Co., El Salado, S. L. P., Mex.

Wilburn, Bertram Victor, Engineering Sales, Western Electric Co., Chicago; res., 817 S. 11th Ave., Maywood, Ill.

Willhardt, Albert, Electrician, Toledo Metal Wheel Co.; res., 1382 W. Woodruff Ave., Toledo, O.

Williams, Lynn Alfred, Patent Attorney, Brown and Williams, 1550 Monadnock Bldg., Chicago; res., 614 Clark St., Evanston, Ill.

Winsor, Paul, Chief Engineer, Motive Power and Rolling Stock, Boston Elevated Railway Co., 101 Milk St., Boston, Mass.

Wishmeyer, Carl, Electrician, Louisville Water Co.; res., 1529 Cherokee Road, Louisville, Ky.

Yamamoto, Tadaoki, Electrical Engineer, Shibaura Engineering Works, Tokyo, Japan.

Yerxa, Russell Armstrong, Wiring and Switchboard Foreman, Stone and Webster Engineering Corporation, Boston, Mass.; res., 1329 Fremont Ave. N., Minneapolis, Minn.

At the same meeting the following Associates were transferred to the grade of Member:

Edward Nelson Lake, Electrical Engineer, 181 La Salle St., Chicago, Ill.

Benjamin Franklin Simmons, Superintendent Holyoke Water Power, Holyoke, Mass.

Arthur Curtis Scott, Professor of Electrical Engineering, University of Texas, Austin, Texas.

Charles Shumway Ruffner, Assistant General Superintendent, Utah Department, Telluride Power Company, Provo, Utah.

Julian Cleveland Smith, General Superintendent, Shawinigan Water and Power Company, Montreal, P. Q.

George Mackenzie Brill, Consulting Engineer, 1154-5 Marquette Bldg., Chicago, Ill.

Joseph Bijur, President and General Manager, General Storage Battery Co., 42 Broadway, New York City.

Oliver Smith Lyford, Jr., Consulting Electrical Engineer, Westinghouse Church, Kerr & Co., 8 Bridge St., New York City.

George Ware Palmer, Jr., Electrical Engineer, Boston & Northern St. Ry. Co., 84 State St., Boston, Mass.

George W. Watts, Works Manager for Canadian General Electric Co., 18 King St. East, Toronto, Canada.

Charles Edward Waddell, Electrical Engineer, Biltmore Estate; Chief Engineer, Weaver Power Co.; Consulting Engineer, Biltmore, N. C.

George Gray Ward, Vice-president and General Manager Commercial Cable Co., 253 Broadway, New York City.

Newitt Jackson Neall, Partner, Thomas & Neall, Electrical Engineers, 12 Pearl St., Boston, Mass.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before July 24, 1908.

7671 Koganey, H., Tokyo, Japan.
7672 Lloyd, S. C., Wilmington, Del.
7673 Bartlett, F. S., Schenectady, N. Y.
7674 Baum, Harry, New York City.
7675 Cooley, G. R., Seattle, Wash.
7676 Bridges, J. E., Alameda, Cal.
7677 Cook, E. W., Jamaica Plain, Mass.
7678 Furness, D. L., Salem, Mass.
7679 Heidenreich, A. H., Cincinnati, O.
7680 Wieland, A. E., Wenatchee, Wash.
7681 Wood, F. P., Deadwood, S. D.
7682 Bard, J. W., Peoria, Ill.
7683 Deal, K. E., Schenectady, N. Y.
7684 Kato, Shizuo, Kobe, Japan.
7685 Bernstein, Fritz, Grand Is. Neb.
7686 Keifer, H. N., Chicago, Ill.
7687 Stambaugh, R. W., Youngstown, O.
7688 Eaton, E. C., Montreal, Que.
7689 Hecksher, Otto, Mexico City, Mex.
7690 Barnes, D. C., Cambridge, Mass.
7691 Hines, G. E., Kansas City, Mo.
7692 Pope, C. C., Beverly, Mass.
7693 Pircher, Frank, New York City.
7694 Sauerhering, R. P., Stillwater, Ok.
7695 Liggett, W. E., Hamburg, Tenn.
7696 Hepburn, F. T., Lima, Ohio.
7697 Swanton, J. A., East Lake, Ala.
7698 Turner, R. A., Springfield, Mass.
7699 Wilson, C. J., Piedmont, Cal.

Total 29

Notes on the Electrical Engineering Department Massachusetts Institute of Technology

Thirty-eight students, ten of whom were already graduates of liberal arts courses, and three graduates of the mechanical engineering course of the Institute, were recently granted the degree of bachelor of science in the electrical engineering course.

Graduate fellowships for electrical engineering study during the next year have been granted to Walter S. Rodman now instructor in electrical engineering at the Rhode Island Agricultural College, and H. S. Osborne who graduates from the electrical engineering course of the Institute this year. Mr. Osborne has been elected Saltonstall Fellow in recognition of his unusual attainments as an undergraduate student.

Professor Laws and Professor Shaad of the electrical engineering department each spent several days during the spring intermission studying the methods of instruction in electrical engineering and related subjects at Cornell University.

Personal

Mr. F. P. Fish has resigned as a director of the General Electric Company, in order to devote all of his time to the practice of law.

Mr. W. C. L. Eglin was elected president of the National Electric Light Association at the convention held in Chicago, on May 19–22, 1908.

Professor A. H. Ford, University of Iowa, married, on June 18, 1908, Miss Sadie Murray Hess, daughter of Mrs. Ellen Murray Hess of Iowa City Iowa.

Mr. W. Montelius Price consulting engineer, who has been located in Philadelphia temporarily, has returned to Seattle, and is doing business at his old location, New York Block.

Mr. H. B. Kirkland has formed the H. B. Kirkland Company, which will hereafter act as selling agent for the National Metal Molding Company with headquarters in the Postal Telegraph Building, New York.

Mr. W. C. Yates, commercial engineer of rheostats and controlling devices for the General Electric Company has moved from Schenectady to New York, and is now located with the company at No. 30 Church Street.

Mr. Alfred E. Seelig, since last December has had charge of the electric meter testing which Columbia University is doing for the Department of Water Supply, Gas and Electricity, under Professor George F. Sever.

Mr. Orman B. Humphrey, electrical engineer, has removed his offices in Bangor, Me., from No. 202 Exchange Street, to No. 96½, same street, where he will continue to give his attention to hydroelectric development and general engineering.

Mr. R. H. Marriott has been transferred from the position of electrical engineer of the Western division of the United Wireless Telegraph Company at Seattle, to assistant scientific manager of the same company with headquarters in New York.

Mr. Arthur M. Waitt, consulting engineer has removed his office from No. 320 Fifth Avenue to the new City Investing Building No. 165 Broadway, where he has taken a suite of offices, Rooms 1417 and 1418, jointly with Frank J. Sprague, consulting engineer.

Mr. Septimus Wilson who has been connected with the erecting department of the Baltimore office of the Westinghouse Electric and Manufacturing Company for the last two years has been transferred to the same department of the San Francisco office of the company.

Mr. I. F. McDonnell, formerly sales manager for the Southern States Electric Co., Atlanta, Ga., has accepted a position with the Western Electric Co., and will represent them in Birmingham and the Birmingham district. He has opened an office at No. 322 Woodward Building.

Mr. James C. Dow, has been engaged by R. E. Brown to make a series of commercial efficiency tests on the electrical generating plant of the Mankato Car and Electric Light Company of Mankato, Minn., with a view to determining the best all-round operating conditions. He will be there several months.

Mr. J. M. Bourse, formerly with the Omaha Electric Light and Power Company, at Omaha, Neb., as engineer in charge of power plant and sub-station construction, has resigned that position and has accepted one as president and general manager of the Eastern Montana Construction Company of Miles

City, Mont., a general engineering and contracting company.

MR. G. F. CHELLIS, of J. G. White & Company who for the past year has been located at Mechanicsville, N. Y. engaged in the installation of electrical apparatus in the new steam turbine generating station of the Delaware and Hudson Railroad Company, has been transferred to Hatfield, Wis., in connection with similar work for the La Crosse Water Power Company.

MR. LEO DOLKART, formerly telephone engineer with the Western Electric Co. at Chicago, has entered the engineering and contracting business in that city with offices at 331 Monadnock Block, Mr. Dolkart is western agent of the Connecticut Telephone and Electric Co. of Meriden, Conn., and will make a specialty of intercommunicating telephone installations, country exchanges, and farmers' lines.

MR. B. E. SUNNY, who recently resigned as vice-president and Western manager of the General Electric Company was elected president of the Chicago Telephone Company on May 13, succeeding Mr. Arthur D. Wheeler, who becomes a chairman of the board of directors. Mr. Sunny is also vice-president of the American Telephone and Telegraph Company, and a director of the General Electric Company.

MR. F. TISCHENDORFER, consulting electrical engineer has removed his office from Berlin to Charlottenburg, Germany, and is now located at No. 167 Berliner street, that city. He is consulting engineer for numerous municipal and private concerns, an expert in patent laws, and sworn expert for electrical engineering at the Berlin courts. He also renders valuable service to American engineering companies and inventors, by finding for them suitable agents and connections on the continent.

MR. ROBERT DAHLANDER has resigned the position of chief engineer for the Swedish State Railways and is now president of the Municipal Gas & Electric Corporation of Stockholm. In 1903 he was employed by the board of directors of the Swedish State Railways as expert to supervise the tests to determine the expediency of adapting electric motive power for propelling the trains and also the relative merits of apparatus then available. This work is now completed, and his report has been submitted to the government. It will be translated into English and German later.

MR. H. H. ADAMS has resigned as superintendent of motive power of the United Railways and Electric Company of Baltimore to become superintendent of rolling stock and shops of the New York City Railway Company. He had been connected with the Baltimore Company since 1902, and prior to that time was master mechanic of the North Jersey Street Railway Company. As superintendent of rolling stock and the shops of the New York corporation, Mr. Adams will be in direct charge of the entire rolling equipment and shops of the company which will operate all the surface lines in the boroughs of Manhattan and Bronx.

Obituary

HENRY CHASE BUCK, who was elected an Associate December 26, 1906, died of heart failure on February 25, 1908, at the American School of Correspondence in Chicago. He was born in Strafford, Vermont, March 27, 1851, and graduated from Tufts College in 1875, receiving the degree of A. B. The following year he received the degree of A.M. For several years he was associated with the Dolbear Telephone Company. He organized and built several gas and electric light plants, and for three years was the New England agent of the Wagner Electric Manufacturing Company of St. Louis. During the last three years he had been an instructor in the electrical engineering department of the American School of Correspondence, at Chicago.

William Arnold Anthony, professor emeritus of physics and electrical engineering in Cooper Institute, New York, died at his home in New York, Friday May 29, 1908 of heart disease at the age of 73 years. He was one of the oldest members of the Institute, having been elected September 25, 1884, when he was professor of physics at Cornell University. In 1886, he was elected a vice-president of the Institute; he was elected president in 1890. Professor Anthony was born in Coventry, R. I., November 17, 1835, and was graduated at the Sheffield Scientific School, Yale University, in 1857. He was professor of physics at the Iowa Agricultural College from 1869 to 1872, thence going to Cornell University, where he remained until 1887. He then entered business as a consulting electrician. In 1895 he became professor of physics and electrical engineering at Cooper Union and in February, 1908, was retired as professor emeritus. He was a member of the Franklin Institute of Philadelphia, the American Social Science Association, the Brooklyn Institute of Arts and Sciences, and the New York Botanical Society. With Professor Cyrus Brackett of Princeton University, he wrote Anthony and Brackett's "Manual of Physics." Of a quiet and unassuming disposition, he nevertheless received full recognition for his work, from an appreciative class of co-workers in the electrical field. He leaves one son, Charles C. Anthony, assistant to the chief of the signal service of the Pennsylvania Railroad.

Mr. Francis Hughes Webb, from 1878 to 1898 secretary of the Institution of Electrical Engineers of Great Britain, died in London, England, on Sunday, May 17, 1908 of Bright's disease from which he had long been a sufferer. The immediate cause of his death was heart failure. Mr. Webb was 84 years old.

Association of Iron and Steel Electrical Engineers

The first annual convention of this association will be held in Philadelphia, Pa., on June 24-25, 1908. The office of the secretary, G.H. Winslow, is at 559 Frick Building, Annex, Pittsburgh, Pa. Committees on finance, papers, library, board of examination, editing, and standardization have recently been appointed by the offices.

Accessions to the Library

The following accessions have been made to the Library of the Institute since the last acknowledgments :

PURCHASES

Boston Transit Commission. Boston Transit Commission, Annual Reports. 1-4, 6-7, 9-10.

Central & South American Cable Expedition, Atlantic Side, 1881-1882.

Central & South American Cable Expedition, Pacific Side, 1881-1882.

Davis, Daniel. Manual of Magnetism. 1847.

Douglas, J. C. Telegraph Construction. Ed. 2. 1877.

Du Moncel, Theodore Comte. Telegraphie electrique. 1864.

Faraday, Michael. Chemical Manipulation. 1831.

Faraday, Michael. Experimental Researches in Chemistry. 1859.

Farrar, John. Elements of Electricity. 1842.

Ferguson, R. M. Electricity. 1866.

Houzeau, Louis. L'appareil Morse. 1864.

Hughes Printing Instrument. n.d.

Bellet, Antonin. Instruction sur l'appareil Hughes. 1872.

Nicholson, Wm. Smoke Abatement. 1905.

Rutherford, E. Radioactivity. 1904.

Thomson, Thomas. Heat and Electricity. 1830.

VARLEY, C. F. Report on the Western Union Telegraph Co. Lines. 1867. (MS.)

———Report on the Western Union Telegraph Co. Lines. 1867. (Facsimile of MS.).

ELEKTROCHEMISCHE ZEITSCHRIFT. Vol. 9. 1902-1903.

STREET RAILWAY GAZETTE. Vol. 7. 1892.

ZEITSCHRIFT DES ELEKTROTECHNISCHEN VEREIN. Vol. 1-4. 1883-86.

GIFTS

Allgemeine Elektricitats Gesellschaft:

Allgemeine Elektricitats Gesellschaft. 1883-1908. [Souvenir.]

American Street and Interurban Railway Association:

American Street Railway Association. Proceedings of Conventions 3-24. 1884-1906.

American Street and Interurban Railway Association. Proceedings of 25th meeting. 1906.

Bureau of Railway News:

THOMPSON, SLASON. Cost, capitalization, and estimated value of American Railways. 1908.

Caldwell, Edward:

New York State Railroad Commission. Annual reports, 1-22. 1855-1856. 1886-1904.

McGraw Publishing Co.:

New York Railroad Commission. Annual reports, 23-24. 1905-1906.

McGraw Electrical Directory. 1908

State of New York. Report of Commission on Gas and Electricity. 1906.

Martin, T. C.:

London. A weekly newspaper. Vol. 1-6. 1893-1897.

New York State Water Supply Commission:

New York State Water Supply Commission. Third annual report. 1908.

New York State Commission of Gas and Electricity:

New York State Commission of Gas and Electricity. Second annual report. 1907.

Rosenthall, L. W.:

Mannheim and Multiplex Slide Rules. Ed. 2. 1908.

Books Received

The following volumes have been received and placed in the Library of the Institute:

THE THEORY, DESIGN AND CONSTRUCTION OF INDUCTION COILS. By H. Armagnat. Translated and edited by Otis Allen Kenyon. New York: McGraw Publishing Company. 1908. Price, $2.00 net.

CONTENTS.—Chapter I.—Introduction. II.—History. III.—Theory of Mechanical Interrupters. IV.—Theory of Electrolytic Interrupters. V.—The Secondary Current. VI.—Power and Efficiency. VII.—Construction of Induction Coils. VIII.—Interrupters. IX.—Special Apparatus. X.—Uses of Induction Coils. XI.—Bibliography. Index.

THE PRODUCTION OF CHROMIUM AND ITS COMPOUNDS BY THE AID OF THE ELECTRIC CURRENT. By Dr. Max Le Blanc. Authorized English translation by Joseph W. Richards, M.A., A.C., Ph.D. 122 pages. Easton, Pa.: The Chemical Publishing Company. 1904. Price, $1.25.

CONTENTS.—Chapter I.—Obtaining of Metallic Chromium. II.—The Obtaining of Compounds of Chromium with Metals. III.—Obtaining of the Compounds of Chromium With the Non-Metals. Appendix.

THE MANUFACTURE OF ELECTRIC LIGHT CARBONS. By O. G. Pritchard. 40 pages. Illustrated. London: "The Electrician" Printing and Publishing Company, Ltd. Price, 1s. 6d. net.

CONTENTS.—Introduction. Preparation of Material. Drying-Rooms. Firing and Carbons. Saturating. Coring. Description of Plant Required. Cost of Plant. Cost of Materials. Cost of Labor. Estimated Profit.

THE PRACTICAL TESTING OF DYNAMOS AND MOTORS. By Charles F. Smith, A.M.I.C.E., A.M.I.E.E. Second and enlarged edition. Illustrated. 306 pages. Price 5s net. Manchester: The Scientific Publishing Company.

Officers and Board of Directors, 1907-1908.

PRESIDENT.

HENRY GORDON STOTT, New York, N. Y.

JUNIOR PAST-PRESIDENTS.

SCHUYLER S. WHEELER, Ampere, N. J.
SAMUEL SHELDON, Brooklyn, N. Y.

VICE-PRESIDENTS.

H. H. HUMPHREY, St. Louis, Mo.
A. H. ARMSTRONG, Schenectady, N. Y.
FRANK G. BAUM, San Francisco, Cal.

JAMES G. WHITE, New York, N. Y.
W. C. L. EGLIN, Philadelphia, Pa.
L. A. FERGUSON, Chicago, Ill.

MANAGERS.

CUMMINGS C. CHESNEY, Pittsfield, Mass.
BANCROFT GHERARDI, New York, N. Y.
CHARLES L. EDGAR, Boston, Mass.
CALVERT TOWNLEY, New Haven, Conn.

JOHN J. CARTY, New York, N. Y.
A. M. SCHOEN, Atlanta, Ga.
PAUL M. LINCOLN, Pittsburg, Pa.
PAUL SPENCER, Philadelphia, Pa.

MORGAN BROOKS, Urbana, Ill.
HAROLD W. BUCK, New York, N. Y.
PERCY H. THOMAS, Montclair, N. J.
BENJAMIN G. LAMME, Pittsburg, Pa.

TREASURER.

GEORGE A. HAMILTON, New York, N. Y.

SECRETARY.

RALPH W. POPE, New York, N. Y.

PAST-PRESIDENTS.

NORVIN GREEN, 1884-5-6.
FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
W. A. ANTHONY, 1890-91.
ALEX. GRAHAM BELL, 1891-2.
FRANK J. SPRAGUE, 1892-3.
EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS B. CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1901.
CHARLES P. STEINMETZ, 1901-2
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, JR., 1904-5.
SCHUYLER S. WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.

ASSISTANT SECRETARY.

FREDERICK L. HUTCHINSON,
33 West 39th Street, New York City, N.Y.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York, N. Y.

Standing Committees.

EXECUTIVE COMMITTEE.

H. G. STOTT, Chairman.
600 W. 59th Street, New York.
C. C. CHESNEY, Pittsfield, Mass.
C. L. EDGAR, Boston, Mass.
GEO. A. HAMILTON, New York.
RALPH W. POPE, New York.
CALVERT TOWNLEY, New Haven, Conn.
JOHN J. CARTY, New York.

FINANCE COMMITTEE.

CALVERT TOWNLEY, Chairman.
Consolidated Railway Co., New Haven, Ct
H. W. BUCK, New York.
BANCROFT GHERARDI, New York.

LIBRARY COMMITTEE.

EDW. CALDWELL, Chairman.
239 West 39th Street, New York.
MORGAN BROOKS, Urbana, Ill.
MAX LOEWENTHAL, New York.
F. A. SCHEFFLER, New York.
PHILIP TORCHIO, New York.

MEETINGS AND PAPERS COMMITTEE.

PERCY H. THOMAS, Chairman.
2 Rector St., New York.
A. H. ARMSTRONG, Schenectady, N. Y.
PAUL M. LINCOLN, Pittsburg, Pa.
RALPH D. MERSHON, New York.
H. H. NORRIS, Ithaca, N. Y.

STANDARDS COMMITTEE.

SAMUEL SHELDON, Chairman.
Polytechnic Institute, Brooklyn, N. Y
B. A. BEHREND, Cincinnati, O.
A. E. KENNELLY, Cambridge, Mass.
D. C. JACKSON, Boston, Mass.
CHAS. F. SCOTT, Pittsburg, Pa.
C. H. SHARP, New York.
C. P. STEINMETZ, Schenectady, N. Y
L. B. STILLWELL, New York.
S. W. STRATTON, Washington, D. C.

EDITING COMMITTEE.

GEORGE F. SEVER, Chairman.
Columbia, University, New York.
W. H. BROWNE, JR., New York.
PERCY H. THOMAS, New York.

BOARD OF EXAMINERS.

HAROLD W. BUCK, Chairman.
49 Wall Street, New York.
H. H. BARNES, JR., New York.
MAURICE COSTER, New York.
W. C. L. EGLIN, Philadelphia, Pa.
GEORGE F. SEVER, New York.

SECTIONS COMMITTEE.

PAUL SPENCER, Chairman.
Broad and Arch Streets, Philadelphia, Pa.
WILLIAM ESTY, Bethlehem, Pa.
H. H. NORRIS, Ithaca, N. Y.
D. B. RUSHMORE, Schenectady, N. Y.
P. B. WOODWORTH, Chicago, Ill.

CODE COMMITTEE.

F. A. C. PERRINE, Chairman.
60 Wall Street, New York.
J. C. FORSYTH, New York.
A. M. SCHOEN, Atlanta, Ga.
GEORGE F. SEVER, New York.
H. A. SINCLAIR, New York.
H. S. WARREN, New York.
ARTHUR WILLIAMS, New York.

LAW COMMITTEE.

C. O. MAILLOUX, Chairman.
76 William Street, New York.
A. H. ARMSTRONG, Schenectady, N. Y.
H. A. LARDNER, New York.
E. A. SPERRY, Brooklyn, N. Y.
C. A. TERRY, New York.

Special Committees.

BUILDING FUND COMMITTEE.

T. C. MARTIN, Chairman.
239 W. 39th Street, New York.
J. C. BARCLAY, New York.
J. J. CARTY, New York.
C. L. EDGAR, Boston, Mass.
F. W. JONES, New York.
J. W. LIEB, Jr., New York.
F. J. SPRAGUE, New York.
J. G. WHITE, New York

COMMITTEE ON INCREASE OF MEMBERSHIP.

D. B. RUSHMORE, Chairman.
Schenectady, N. Y.
A. W. BERRESFORD, Milwaukee.
S. S. DICKENSON, New York.
GANO DUNN, Ampere, N. J.
BANCROFT GHERARDI, New York.
F. L. HUTCHINSON, New York.
S. M. KINTNER, Pittsburg.
A. P. PECK, New York.
W. L. WATERS, Milwaukee.

HIGH-TENSION TRANSMISSION COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
RALPH D. MERSHON, Chairman.
60 Wall Street, New York.
P. G. BAUM, San Francisco.
C. C. CHESNEY, Pittsfield, Mass.
B. G. LAMME, Pittsburg.
PAUL M. LINCOLN, Pittsburg.
W. S. MOODY, Schenectady.
W. N. RYERSON, Niagara Falls, N. Y.

JOHN FRITZ MEDAL REPRESENTATIVES.

HENRY G. STOTT.
SAMUEL SHELDON.
SCHUYLER S. WHEELER.
JOHN W. LIEB, Jr.

RAILWAY COMMITTEE

(Sub-com. of Meetings and Papers Committee.)
A. H. ARMSTRONG, Chairman.
Schenectady, N. Y.
WM. McCLELLAN, New York.
H. ST. C. PUTNAM, New York.
C. W. RICKER, Cleveland, O.
N. W. STORER, Pittsburg, Pa.

CODE OF ETHICS COMMITTEE.

SCHUYLER S. WHEELER, Chairman,
Ampere, N. J.
BION J. ARNOLD, Chicago.
H. W. BUCK, New York.
J. J. CARTY, New York.
L. A. FERGUSON, Chicago, Ill.
B. G. LAMME, Pittsburg.
J. W. LIEB Jr., New York.
C. F. SCOTT, Pittsburg.
SAMUEL SHELDON, Brooklyn.
C. P. STEINMETZ, Schenectady, N. Y.
L. B. STILLWELL, New York.

EDUCATIONAL COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
HENRY H. NORRIS, Chairman,
Cornell University, Ithaca, N. Y.
GANO DUNN, Ampere, N. J.
DUGALD C JACKSON, Boston, Mass.
C. O. MAILLOUX, New York.
CHARLES F. SCOTT, Pittsburg, Pa.

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

United States National Committee.

ELIHU THOMSON, President, Lynn, Mass.
CHARLES F. SCOTT, 1st Vice-president.
SAMUEL SHELDON, 2d Vice-president.
BION J. ARNOLD,
B A. BEHREND,
ARTHUR W. BERRESFORD,
JOHN J. CARTY,
W. C. L. EGLIN,
CARL HERING,
JOHN W HOWELL,
DUGALD C. JACKSON,
FRANCIS W. JONES,
ARTHUR E. KENNELLY,
BENJAMIN G. LAMME,
W. A. LAYMAN,
JOHN W. LIEB, Jr.,
CLAYTON H. SHARP,
CHARLES P. STEINMETZ,
LEWIS B. STILLWELL,
HENRY G. STOTT,
SAMUEL W. STRATTON

COMMITTEE ON FOREST PRESERVATION.

C. H. PORTER, Chairman.
Mass. Inst. Technology, Boston.
R. G. BLACK, Toronto, Ont.
P. G. GOSSLER, New York.
A. M. SCHOEN, Atlanta, Ga.
J. A. THALER, Bozeman, Mont.
C. A. WADDELL, Biltmore, N. C.

COMMITTEE ON BIBLIOGRAPHY.

WM. D. WEAVER, 239 W. 39th St., New York.

Sections and Branches—Directory.

Name and when Organized.	Chairman.	Secretary.	Regular Meeting.
SECTIONS.			
Atlanta............Jan. 19, '04	J. H. Finney.	G. J. Yundt.	1st Tuesday.
Baltimore.........Dec. 16, '04	J. B. Whitehead.	C. G. Edwards.	2d Friday.
Boston............Feb. 13, '03	Wm. L. Puffer.	A. L Pearson.	3d Wednesday
Chicago..................1893	H. R. King.	J. G. Wray.	1st Tuesday after N. Y. meeting.
Cincinnati.........Dec. 17, '02	A. G. Wessling.	A. C. Lanier.	3d Wednesday.
Cleveland.........Sept. 27, '07	Henry B. Dates.	F. M. Hibben.	3d Monday.
Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Bachman.	1st Wednesday.
Ithaca............Oct. 15, '02	E. L. Nichols.	H. H. Norris.	1st Friday after N. Y. meeting.
Los Angeles........May 19, '08			
Mexico...........Dec. 13, '07	R. F. Hayward.	F. D. Nims.	
Minnesota..........Apr. 7, '02	E. H. Scofield.	A. L. Abbott.	2d Monday after N. Y meeting.
Norfolk...........Mar. 13, '08	R. R. Grant.	F. W. Walter.	
Philadelphia.......Feb. 18, '03	J. F. Stevens.	H. F. Sanville.	2d Monday.
Pittsburg..........Oct. 13, '02	C. E. Skinner.	R. A. L. Snyder.	1st Wednesday.
Pittsfield..........Mar. 25, '04	J. Insull.	H. L. Smith.	3d Friday.
San Francisco......Dec. 23, '04	A. M. Hunt.	G. R. Murphy.	4th Friday.
Schenectady.......Jan. 26, '03	D. B. Rushmore.	W. C. Andrews.	Every Friday.
Seattle............Jan. 19, '04	J. H. Harisberger.	George H. Moore.	3d Saturday.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	H. I. Finch.	2d Wednesday
Toledo............ June 3, '07	C. R. McKay.	Geo. E. Kirk.	1st Friday.
Toronto..........Sept. 30, '03	W. A. Bucke.	W. G. Chace.	2d Friday.
Urbana...........Nov. 25, '02	J. M. Bryant.	E. B. Paine.	1st Wednesday after N.Y. meeting.
Washington, D. C...Apr. 9, '03.	P. G. Burton.	Philander Betts.	2d Wednesday.

Sections and Branches—Directory.

Name and when Organized.	Chairman.	Secretary.	Regular Meeting.
BRANCHES.			
Univ. of Arkansas..Mar. 25, '04	M. F. Thompson.	C. R. Rhodes.	Alternate Mondays.
Armour Institute...Feb. 26, '04	T. C. Oehne, Jr.	J. E. Snow.	1st & 3d Thursdays.
Univ. of Cincinnati..Apr. 10, '08	C. R. Wylie.	C. C. Buchanan.	
Univ. of Colorado..Dec. 16, '04	L. R. Handley.	H. S. Buchanan.	1st and 3d Wednesdays.
Iowa State College..Apr. 15, '03	F. A. Fish.	Adolph Shane.	1st and 3d Wednesdays.
Kansas State Agr. Col., Jan. 10, '08	W. L. Enfield.	Kirk H. Logan.	
Univ. of Kansas....Mar. 18, '08	Martin E. Rice.	H. P. Broderson.	Alternate Thursdays
Lehigh University..Oct. 15, '02	H. O. Stephens.	J. A. Clarke, Jr.	2d Tuesday.
Lewis Institute.....Nov. 8, '07	W. H. Hayes.	P. B. Woodworth.	2d Wednesday.
Univ. of Maine.....Dec. 26, '06		Gustav Wittig.	
Univ. of Michigan..Mar. 25, '04	C. M. Davis.	H. F. Baxter.	1st and 3d Wednesdays.
Univ. of Missouri..Jan. 10. '03	H. B. Shaw.	H. D. Carpenter.	1st and 3d Fridays.
Univ. of Montana..May 21, '07	Robert Sibley.	S. R. Inch.	1st Thursday.
Montana Agr. Col..May 21, '07	C. M. Fisher.	J. A. Thaler.	1st Friday.
Univ. of Nebraska..Apr. 10, '08	George H. Morse.	L. E. Hurtz.	
Ohio State Univ....Dec. 20, '02	F. W. Funk.	F. C. Caldwell.	Alternate Wednesdays.
Oregon State Agr. Col., Mar. 24, '08	E. V. Hawley.	E. C. Wiggin.	
Penn. State College. Dec. 20, '02	D. R. Simpson.	C. D. Preston.	Every Wednesday
Purdue University..Jan. 26, '03	J. W. Esterline.	H. T. Plumb.	Every Tuesday.
Stanford Univ......Dec. 13, '07	W. C. North.	A. J. Gowan.	
Syracuse Univ.....Feb. 24, '05	W. P. Graham.	R. A. Porter.	1st and 3d Thursdays.
Univ. of Texas.....Feb. 14, '08	A. C. Scott.	B. F. Kenyon.	2d and 4th Fridays.
State Col. of Wash..Dec. 13, '07	H. V. Carpenter.	M. K. Akers.	3d Tuesday.
Washington Univ..Feb. 26, '04	W. A. Burnet.	W. E. Beatty.	2d and 4th Wednesdays.
Univ. of Wisconsin. Oct. 15, '02	O. H. Ensign.	J. W. Shuster.	Every Thursday. [4th Thursday (Public Meeting.)]
Worcester Poly. Inst. Mar. 25, '04	L. W. Hitchcock	W. D. Stearns.	Alternate Fridays.

Section and Branch Secretaries.

AMES, IOWA.—ADOLPH SHANE,
Iowa State College.

ANN ARBOR, MICH.—H. F. BAXTER,
556 S. State St.

ATLANTA, GA.—G. J. YUNDT,
Southern Bell Tel. & Tel. Co.

AUSTIN, TEXAS.—B. F. KENYON,
University of Texas

BALTIMORE, MD.—CHAS. G. EDWARDS,
Electrical Commission, City Hall

BETHLEHEM, PA.—J. A. CLARKE, Jr.,
Lehigh University.

BOSTON, MASS.—A. L. PEARSON,
93 Federal St.

BOULDER, COLO.—H. S. BUCHANAN,
University of Colorado.

BOZEMAN, MONT.—J. A. THALER,
Montana Agricultural College.

CHICAGO, ILL.—J. E. SNOW,
Armour Inst. of Technology.

CHICAGO, ILL.—P. B. WOODWORTH,
Lewis Institute.

CHICAGO, ILL.—J. G. WRAY,
Chicago Telephone Co.

CINCINNATI, O.—A. C. LANIER,
University of Cincinnati.

CINCINNATI, O.—C. C. BUCHANAN,
University of Cincinnati.

CLEVELAND, O.—F. M. HIBBEN,
10207 Wilbur Avenue.

COLUMBIA, MO.—H. D. CARPENTER,
University of Missouri.

COLUMBUS, O.—F. C. CALDWELL,
Ohio State University.

COLUMBUS, O.—H. L. BACHMAN,
533 South 3d St

CORVALLIS, ORE.—E. C. WRIGHT,
Oregon Agr. College.

FAYETTEVILLE, ARK.—C. R. RHODES,
University of Arkansas.

ITHACA, N. Y.—H. H. NORRIS,
Franklin Hall, Cornell University.

LAFAYETTE, IND.—H. T. PLUMB,
Electrical Eng. Dept., Purdue University

LAWRENCE, KAN.—H. P. BRODERSON,
University of Kansas.

LINCOLN, NEB.—L. E. HURTZ,
Lincoln Tel. Co.

MADISON, WIS.—J. W. SHUSTER,
University of Wisconsin.

MANHATTAN, KAN.—KIRK H. LOGAN,
Kansas State Agr. College.

CITY OF MEXICO.—F. D. NIMS,
Mexican Light & Power Co.

MISSOULA, MONT.—S. R. INCH,
Univ. of Montana.

NORFOLK, VA.—F. W. WALTER,
National Bank of Commerce.

ORONO, MAINE,—GUSTAV WITTIG,
University of Maine.

PENN. STATE COLLEGE, PA.—C. D. PRESTON,
Penn. State College.

PHILADELPHIA, PA.—H. F. SANVILLE,
1122 North American Building.

PITTSBURG, PA.—R. A. L. SNYDER,
1332 Fulton Building.

PITTSFIELD, MASS.—H. L. SMITH,
Stanley-G. I. Elec. Mfg. Co.

PULLMAN, WASH.—M. K. AKERS,
State College of Washington.

ST. LOUIS, MO.—C. M. DUNCAN,
Washington University.

ST. LOUIS, MO.—H. I. FINCH,
5217 Morgan Street.

ST. PAUL, MINN.—A. L. ABBOTT,
165 E. 4th St.

SAN FRANCISCO, CAL.—G. R. MURPHY,
11 Hawthorne St., San Francisco.

SCHENECTADY, N. Y—W. C. ANDREWS,
General Electric Co.

SEATTLE, WASH.—GEORGE H. MOORE,
1726 Harvard Ave.

STANFORD UNIVERSITY.—A. J. GOWAN,
Leland Stanford, Jr., University.

SYRACUSE, N. Y.—R. A. PORTER,
Syracuse University.

TOLEDO, OHIO.—GEO. E. KIRK,
The Nicholas.

TORONTO, ONT.—W. G. CHACE,
126 Confederation Life Building.

URBANA, ILL.—ELLERY B. PAINE,
University of Illinois.

WASHINGTON, D. C.—PHILANDER BETTS,
Metropolitan Bank Bldg.

WORCESTER MASS.—S. W. FARNSWORTH,
Worcester Poly. Inst.

Local Honorary Secretaries.

JAMES S. FITZMAURICE,
210 George St., Sydney, N. S. W.

H. F. PARSHALL,
Salisbury House, London Wall E. C., London.

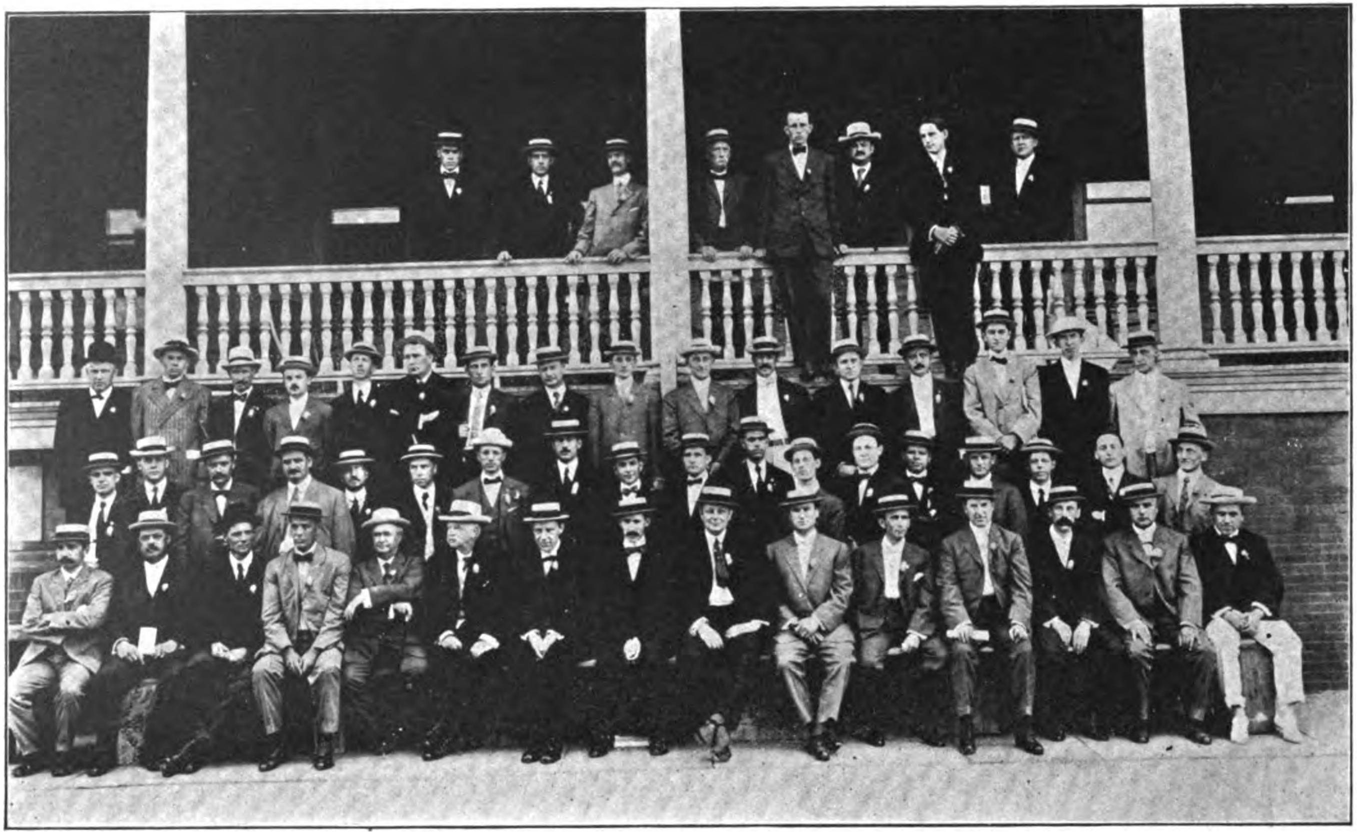
ROBERT B. OWENS,
McGill University, Montreal, P. Q.

WILLIAM B. HALE,
1a Independencia No. 6, City of Mexico

CLARE F. BEAMES,
for Porto Rico and West Indies,
San Juan, P. R.

W. G. T. GOODMAN,
Adelaide, South Australia.

ROBERT J. SCOTT,
Christ Church, New Zealand.



Convention of the A. I. E. E. at Atlantic City, N. J., June 29–July 2, 1908

PROCEEDINGS
OF THE
American Institute
OF
Electrical Engineers.

Published monthly at 33 W. 39th St., New York,
under the supervision of

THE EDITING COMMITTEE
GEORGE F. SEVER, Chairman
PERCY H. THOMAS W. HAND BROWNE, Jr.

GEORGE A. WARDLAW, Editor

Subscription. United States, Mexico and Cuba, $5.00 per year.
All other countries $6.00 per year.
Single copy 50 cents.
Subscriptions must begin with January issue.

Advertisements accepted from reputable concerns at the following net rates:

Space	Less than half year per issue	Half year per issue	One year per issue
1 page	$36.00	$32.00	$30.00
½ page	22.00	18.00	16.00

Additional charges for Preferred Positions.
Professional Cards, special rate of $25.00 per year.

Vol. XXVII **August, 1908** No. 8

Section Papers

IN order to make clear to all, the basis on which the papers read before the Sections during the past year and sent to the secretary of the Institute for consideration, have been judged, the retiring chairman of the Meetings and Papers Committee wishes to make the following explanation. All such papers have been examined when received, either by the chairman or some other properly qualified person, and when found to meet the general standard that has been set up for the regular meetings of the Institute, have been accepted for publication. There have been some papers of merit which have not been on subjects quite in line with the usual custom, and which, though perfectly appropriate for Section meetings where local conditions dominate, have not been published. No Section papers have been published in the last two issues of the PROCEEDINGS, since all the available space was occupied by the convention papers.

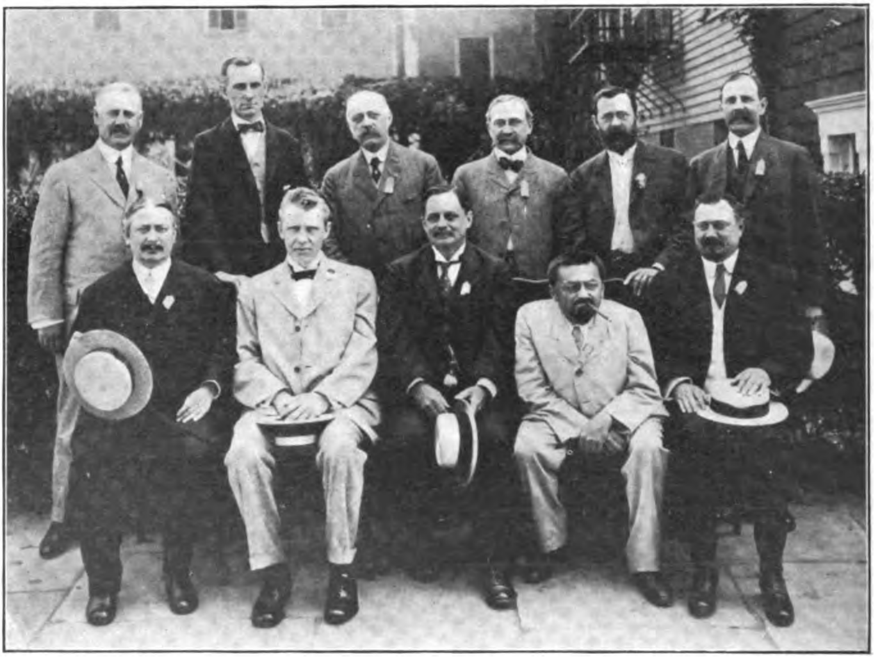
The chairman of the committee, Mr. Thomas, wishes to offer an apology for the delay that has occurred in the consideration of some of the Section papers that have been sent in, especially during the preparation of the convention program. He has found it impossible to keep up with the demands on his time. Papers have, however, received relatively prompt attention wherever it has been stated that they were wanted for publication elsewhere if not accepted for the PROCEEDINGS.

Institute Publications

A VERY important duty which every member of the Institute can undertake, is to correct the erroneous impression that the technical press publishes everything of value that is printed in the PROCEEDINGS. While the Institute places no restriction upon reprinting its papers and discussions, the amount of important matter published is so great that our exchanges cannot undertake to print it in full. Non-members not familiar with the work of the Institute do not always realize what they miss, and frequently apply for copies of papers which are out of print. Notable instances of this nature are the papers by H. A. Foster on the " Cost of Steam Power ", by Dr. M. I. Pupin, on " Wave Transmission over Non-uniform Cable and Long-distance Air-lines " and C. O. Mailloux on " Speed Time Curves." As all important papers and discussions printed in Section II of the PROCEEDINGS are subsequently included in the TRANSACTIONS, membership in the Institute has a permanent value to the electrical engineer which can only be appreciated by actual participation in its work.

Twenty-fifth Annual Convention

The twenty-fifth annual convention of the American Institute of Electrical Engineers, held at Atlantic City, N. J., from June 29 to July 2, was undoubtedly the most successful meeting ever held by the A. I. E. E. While the attendance in point of members was not above the average attendance at the Institute conventions during recent years—there were 469 members and guests—yet the proportion of prominent and well-known electrical engineers present and active in one way or another at one or more of the sessions was much greater than usual. Including President-elect Louis A. Ferguson, there were present no less than twelve men that have been honored with the office of president: Charles P. Steinmetz, Charles F. Scott, Schuyler Skaats Wheeler, Henry G. Stott, T. Commerford Martin, Carl Hering, Samuel Sheldon, Louis Duncan, John W. Lieb, Jr., Arthur E. Kennelly, and Elihu Thomson—all were there engaged in looking after the welfare of the Institute. Commenting on this interesting feature of the convention at one of the sessions, President Stott said: " As a nation we frequently find ourselves asking, ' What shall we do with our ex-presidents? ' As a national engineering society we ask the same question and then answer it by saying, ' We make them continue to work for the Institute.' There are ten of them here now, disinterestedly doing this very thing."


Group of Past-Presidents of the A. I. E. E.
Atlantic City Convention, June 29-July 2, 1908

Socially, too, the twenty-fifth annual convention of the Institute was probably the most delightful of all the social affairs in which the Institute has been interested. The reception and dance given at the Casino on June 29, under the auspices of the convention committee was afterward commented on as more of the nature of an informal home social affair, than of an open convention dance. Besides this function there were many other social features, such as little dinner parties, teas at the Atlantic City Golf Club, sailing parties, and evening informal dances in the pavilion on the Steel Pier.

Including President Henry G. Stott's address on "The Evolution of Engineering", there were presented for discussion thirty-five papers, covering approximately 775 pages of the Institute PROCEEDINGS. There were eight separate sessions, taking up a total of 26 hours' time, devoted to technical papers and discussions, beginning at eleven a.m. on Monday, June 29, and ending at five p.m. on Thursday, July 2. Owing to the large number of valuable and interesting papers presented, they were read in abstract only in order to give more time for discussions. The discussions were animated and extended, no less than one hundred and twenty-five members taking part in them, and in addition there were a number of contributions by letter. The discussions will cover approximately 200 pages of the PROCEEDINGS. [These discussions will be put in type as soon as the stenographer's notes are revised by the various authors and approved by the Editing Committee; they will be published in the PROCEEDINGS as soon as practicable after the various authors have approved and returned the galley-proofs.]

The Institute headquarters during the convention were at the Hotel Traymore, and the convention sessions were held in the hotel sun parlor, facing the Atlantic Ocean. The convention program was carried out, as follows:

Monday, June 29

MORNING SESSION—11 A.M. TO 12.30 P.M.

1. Address of Welcome.
2. President's Address: by HENRY G. STOTT.

Immediately after the speech of welcome by Mayor Stoy of Atlantic City, President Henry G. Stott read the president's address, entitled "The Evolution of Engineering." President Stott said that more progress had been made in the engineering world during the last 80 years than in the period of 4,500 years preceding the formulation of Tredgold's famous definition. The progress has been so great and the conditions under which the engineer plies his tasks are now so radically different that Tredgold's definition fails properly to reflect the conditions under which modern engineering practice is carried on.

President Stott made an earnest appeal to engineers in general to be less passive and more aggressive in their allegiance to their engineering societies, to take a more active and potent interest in the political, economic and social affairs of the world—in short, to keep control of the machinery that they have so largely created. The address concludes with a new and broader definition of engineering than that formulated by Tredgold: "Engineering—the art of organizing and directing men, and of controlling the forces and materials of nature for the benefit of the human race."

[This address is printed in Section II of this PROCEEDINGS.]

3. C. M. GODDARD, "Electricity as Viewed by the Insurance Engineer. Should the A.I.E.E. Interest Itself in Fire Protection?"
4. F. G. BAUM, "Water Power Development in the National Forests. A Suggested Government Policy."

Following the presentation of the papers, President Stott introduced President-elect Louis A. Ferguson of Chicago. In an interesting and brief off-hand address, Mr. Ferguson outlined his policy regarding the executive administration of the Institute during the coming year. He said that the welfare of the Institute would undoubtedly be furthered if a larger number of young men could be brought to appreciate the benefits arising from active Institute work; that the Institute's interests would be still further advanced if more men of broad executive training could be induced to give the Institute the benefit of their experience and judgment.

AFTERNOON SESSION—2 P.M. TO 5 P.M.

5. W. LEE CAMPBELL, " A Study of Multioffice Automatic Switchboard Telephone Systems."
6. R. A. FESSENDEN, " Wireless Telephony."
7. A. E. KENNELLY and S. E. WHITING, " The Measurement of Rotary Speeds of Dynamo Machines by the Stroboscopic Fork."
8. CHAS. E. WADDELL, " Notes on the Electric Heating Plant of the Biltmore Estate."

As mentioned in the second paragraph, a delightful reception followed by a dance was given in the Casino on Monday evening, June 29.

Tuesday, June 30

MORNING SESSION–9.30 A.M. TO 12.30 P.M.

9. E. E. F. CREIGHTON, " Measurements of Lightning, Aluminum Lightning-Arresters, Earth Resistances, Cement Resistances and Kindred Tests."
10. ERNST J. BERG, " Tests with Arcing Grounds and Connections."
11. AUSTIN BURT, " Three-Phase Power Factor."
12. PERCY H. THOMAS, " Critical Study of Lightning Records on Taylor's Falls Transmission Line."
13. J. W. FRASER, " Engineering Features of the Southern Power Company's Systems."

On Tuesday afternoon, June 30, there was a putting contest for the women, followed by a tea at the picturesque links of the Atlantic City Golf Club. This affair, as well as all the other social amenities, was given under the auspices of the Convention Committee, consisting of W. C. L. Eglin, Charles Day, J. J. Gibson, Nathan Hayward, H. F. Sanville, and Paul Spencer.

EVENING SESSION—8 P.M. TO 10.30 P.M.

14. RALPH D. MERSHON. " High-Voltage Experiments at Niagara."
15. D. R. SCHOLES, " Fundamental Considerations Governing the Design of Transmission Line Structures."
16. C. E. SKINNER, " The Testing of High-Voltage Line Insulators."

Before opening the discussion on these papers, President Stott announced that at a meeting of the Board of Directors on February 14, 1908, there were adopted resolutions of appreciation of the work done by Past-president Charles F. Scott of Pittsburg in connection with the inception, construction, completion, and administration of the Engineers' Building in New York. Before the entire convention assemblage in the meeting hall, Past-president Samuel Sheldon of Brooklyn then presented Mr. Scott with a set of tastefully engrossed and framed resolutions, reproduced in facsimile on page 5 of this PROCEEDINGS. With characteristic modesty Mr. Scott acknowledged this additional honor in a few appropriate words.

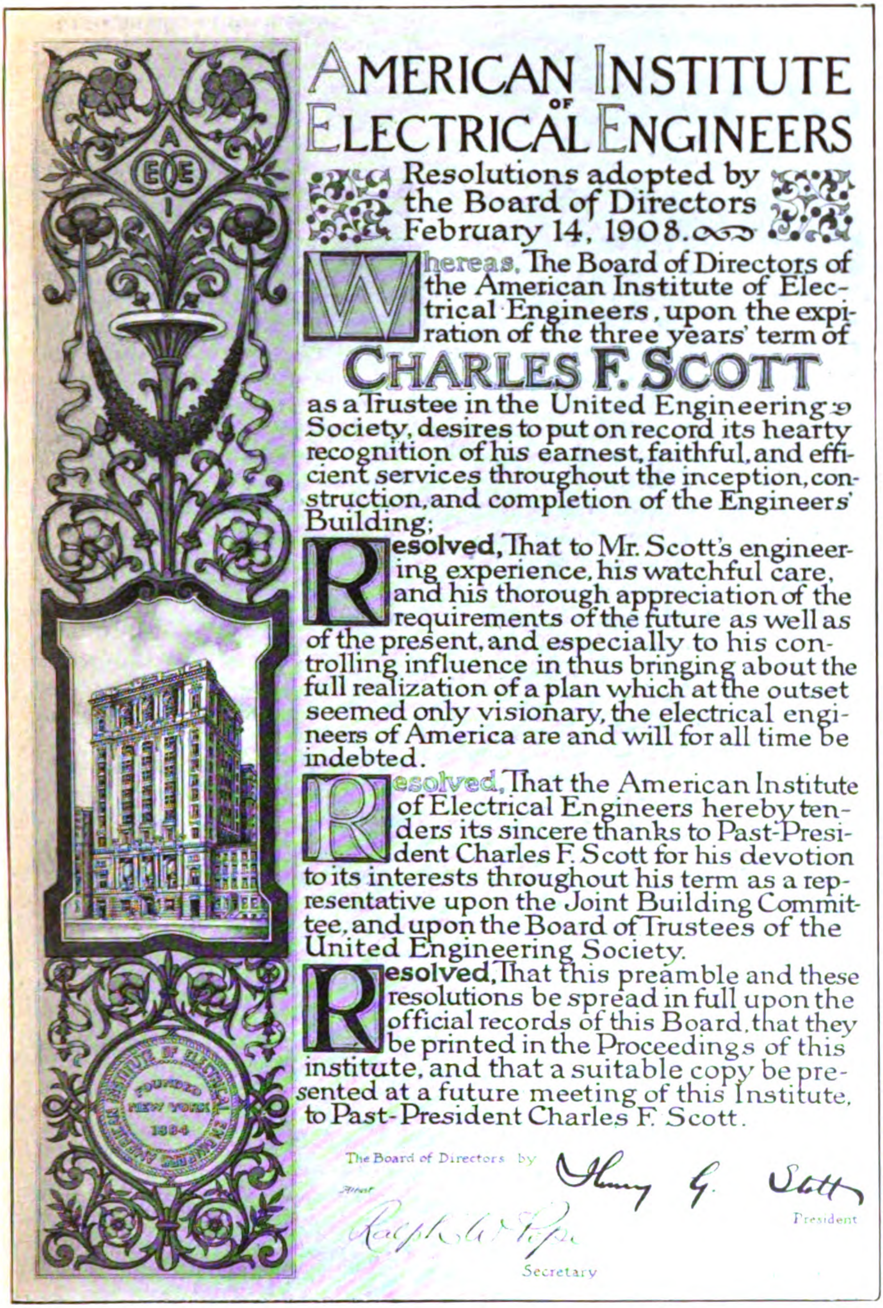
Wednesday, July 1

MORNING SESSION–9.30 A.M. TO 12.30 P.M.

17. COMFORT A. ADAMS, " Voltage Ratio in Synchronous Converters, with Special Reference to the Splitpole Converter."
18. J. LESTER WOODBRIDGE, " Application of Storage-Batteries to Regulation of Alternating-Current Systems."
19. B. A. BEHREND, " A New Large Generator for Niagara Falls."
20. W. L. WATERS, " Modern Developments in Single-Phase Generators."
21. JENS BACHE-WIIG, " Application of Fractional-Pitch Windings to Alternating-Current Generators."
22. J. R. BIBBINS, " Double-Deck Steam Turbine Power Plants."
23. J. R. BIBBINS, " Working Results from Gas-Electric Power Plant. Report of 30 Day Test on Service Plant, Richmond Works, American Locomotive Company."

AFTERNOON SESSION—2 P.M. TO 5 P.M.

24. J. B. WHITEHEAD, " From Steam to Electricity on a Single-Track Road."



AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Resolutions adopted by the Board of Directors February 14, 1908.

Whereas, The Board of Directors of the American Institute of Electrical Engineers, upon the expiration of the three years' term of

CHARLES F. SCOTT

as a Trustee in the United Engineering Society, desires to put on record its hearty recognition of his earnest, faithful, and efficient services throughout the inception, construction, and completion of the Engineers' Building;

Resolved, That to Mr. Scott's engineering experience, his watchful care, and his thorough appreciation of the requirements of the future as well as of the present, and especially to his controlling influence in thus bringing about the full realization of a plan which at the outset seemed only visionary, the electrical engineers of America are and will for all time be indebted.

Resolved, That the American Institute of Electrical Engineers hereby tenders its sincere thanks to Past-President Charles F. Scott for his devotion to its interests throughout his term as a representative upon the Joint Building Committee, and upon the Board of Trustees of the United Engineering Society.

Resolved, That this preamble and these resolutions be spread in full upon the official records of this Board, that they be printed in the Proceedings of this institute, and that a suitable copy be presented at a future meeting of this Institute, to Past-President Charles F. Scott.

The Board of Directors by Henry G. Stott
President

Attest Ralph W. Pope
Secretary

Engrossed Resolutions presented to Past-President Charles F. Scott, at the Atlantic City Convention, Tuesday evening, June 30, 1908

25. H. C. Specht, "Induction Motors for Multispeed Service with Particular Reference to Cascade Operation."
26. Gerard B. Werner, "The Determination of the Economic Location of Sub-Stations in Electric Railways."
27. S. B. Fortenbaugh, "Conductor Rail Measurements."

One of the most interesting features of the convention was the informal meeting of the officers of the Institute, the Sections Committee, and the representatives of the Sections and Branches, on Wednesday evening, July 1. Nearly all of the 22 Sections and 26 Branches were represented at the meeting, which was presided over by Mr. Paul Spencer, chairman of the Sections Committee. At this meeting Mr. Spencer invited free and full expressions of opinion from all the representatives present, asking particularly for practical suggestions for closer working relations between the Sections and Branches and Institute headquarters. An interesting discussion, lasting from 8 to 11:30 p.m., followed this invitation.

Thursday, July 2

MORNING SESSION 9.30 A.M. TO 12.30 P.M.

28. C. P. Steinmetz, "The General Equations of the Electric Circuit."
29. C. P. Steinmetz, "Primary Standard of Light."
30. Carl Hering, "An Imperfection in the Usual Statement of the Fundamental Law of Electromagnetic Induction." (With discussions by letter)
31. R. E. Hellmund, "Graphical Treatment of the Rotating Field."
32. Harold Pender, "A Minimum-Work Method for the Solution of Alternating-Current Problems."
33. Carl J. Fechheimer, "The Relative Proportions of Copper and Iron in Alternators."

AFTERNOON SESSION - 2 P.M. TO 5 P.M.

34. M. W. Alexander, "A New Method of Training Engineers."
35. D. B. Rushmore, "The Relation of the Manufacturing Company to the Technical Graduate."
36. B. A. Behrend, "The Relation of the Manufacturing Company to the Technical Graduate."

At the closing session on Thursday afternoon, in addition to the customary acknowledgments to the Convention Committee, the Convention voted its appreciation of the assistance rendered by the Philadelphia Section, the proprietor of the Brighton Casino, and the untiring, faithful, and able services of President Stott and the various committees during the last year, in many ways probably the most successful year in the history of the Institute.

Report of the Sections Committee

Philadelphia, Pa., May 16, 1908

To the Board of Directors of the American Institute of Electrical Engineers.

Gentlemen: The Sections Committee would submit the following report of the work of the Committee for the year ending April 30, 1908:

There are at present 22 Sections, located in the following cities:

Atlanta, Ga.
Baltimore, Md.
Boston, Mass.
Chicago, Ill.
Cincinnati, O.
Cleveland, O.
Columbus, O.
Ithaca, N. Y.
Mexico, Mex.
Minneapolis-St. Paul, Minn.
Norfolk, Va.
Philadelphia, Pa.
Pittsburgh, Pa.
Pittsfield, Mass.
San Francisco, Cal.
Schenectady, N. Y.
Seattle, Wash.
St. Louis, Mo.
Toledo, O.
Toronto, Canada.
Urbana, Ill.
Washington, D. C.

This list shows an increase of 4 Sections since May 1, 1907, the date of the last report of the Sections Committee.

The following are the Sections which have been added since that date:

Toledo	Authorized	June 3, 1907
Cleveland	"	Sept. 27, 1907
Mexico	"	Dec. 13, 1907
Norfolk	"	Mar. 13, 1908

In addition to the above Sections, there are at present 26 Branches, organized in the following universities and colleges:

University of Arkansas.
Armour Institute.
University of Colorado.
Iowa State College
Kansas State Agricultural College
University of Kansas
Lehigh University
Lewis Institute
University of Michigan
University of Missouri
University of Montana
Montana Agricultural College
Pennsvlyania State College
Purdue University
Stanford University
Syracuse University
Washington State College
Washington University
University of Wisconsin
Worcester Polytechnic Institute
Ohio State University
Oregon State College
University of Texas
University of Maine
University of Nebraska
University of Cincinnati

Of the above, 11 have been organized since May 1, 1907, the date of the last report of the Sections Committee, as follows:

Branch	*Date Authorized*
Montana Agricultural College,	May 21, 1907
University of Montana,	May 21, 1907
Lewis Institute,	Nov. 8, 1907
Stanford University,	Dec. 13, 1907
State College of Washington,	Dec. 13, 1907
Kansas State Agricultural College,	Jan. 10, 1908
University of Texas,	Feb. 14, 1908
University of Kansas,	Mar. 13, 1908
Oregon State College,	Mar. 13, 1908
University of Nebraska	April 10, 1908
University of Cincinnati,	April 10, 1908

In addition to the above lists of Sections and Branches which have been started during the past year, there have been inquiries from 12 different cities, located at widely scattered points throughout the country, suggesting the formation of Sections in their territory. These inquiries have not been brought to the attention of the Board of Directors, as the Sections Committee has felt that it would be wise to postpone the formation of Sections in these cities until the membership in their various territories had been increased.

These inquiries, however, received from so many widely scattered sections of the country, indicate the interest which is taken in the Sections work by the membership at large.

It has not been the policy of the present Sections Committee to encourage the formation of new Sections, except in localities where there is a real need for them. It is believed that the initiative should come from the local membership, and that new Sections should be encouraged only in localities where there is sufficient present membership to enable the work to be carried on successfully. It was with this idea of restricting the organization of new Sections that the committee proposed to the Board of Directors the amendment to the By-laws, raising the number required to sign a petition for the formation of a Section to 25 Members and Associates residing in the territory of the proposed Section. This amendment to the By-laws was adopted by the Board of Directors, and under its restrictions it has not been possible to encourage the formation of Sections in these various localities.

It is believed by the Sections Committee that the policy of limiting the Sections to the more thickly settled centres of electrical interest is a wise one, and that it should be maintained, and that it may even be found desirable to increase the requirements as to the number of members necessary for the organization of a Section.

As far as the formation of University Branches is concerned, the committee has adopted a somewhat different policy. The provisions of the Constitution and of the By-laws are extremely liberal in allowing University Branches to be formed under the authorization of the Board of Directors in any institution of recognized standing, maintaining a course in electrical engineering, and where a Member or Associate connected with the institution desires to form such an organization. These organizations entail little or no expense upon the Institute, and their influence should be of great importance in acquainting engineers at the beginning of their careers with the work of the Institute, and it has seemed wise to the committee to adopt a most liberal policy toward their formation.

The Student enrolment is largely increased through these organizations, and this Student enrolment should form a most desirable feeder to the Associate membership of the Institute. At present it would seem as if the Institute is not obtaining the full possible benefits from its Students. Many Students do not become Associates at the expiration of their period of enrolment as Students, but automatically cease their connection with the Institute. The Sections Committee endeavored during the past year to draft amendments to the By-laws which would provide for enrolled Students automatically becoming Associates, but was unable to accomplish this under the requirements of the Constitution.

The committee would, however, recommend to the Membership Committee, and to the permanent office of the Institute, that every possible means be taken to encourage the Students to become Associates at the end of their period of enrolment as Students.

We believe that the work of the Sections and Branches has been carried on during the past year somewhat more systematically and with better results than heretofore. The meetings of most of the Sections have been held with regularity, and there has been a large number of original papers presented, some of which have been published in the PROCEEDINGS.

We attach a sheet which gives a partial summary of the meetings held at the Sections and Branches during the year. This summary is, unfortunately, not complete, as it is compiled from the regular reports sent in by the different secretaries, and these reports are not sent in with the regularity that could be desired, and many meetings have been held and papers presented which are not included in the reports received. The lists are, however, sufficiently complete to show that the work has been carried on during the past year with even greater activity than heretofore.

The Sections Committee has prepared and published a set of rules for the guidance of the Sections, so as to provide for a somewhat more systematic method of carrying on their work, and to acquaint them with the necessary routine to be followed, in connection with their reports, finances and other details.

The question of expenses has been in the past year, as heretofore, on a somewhat unsatisfactory basis. The Board of Directors treated this matter with liberality, granting the full amount of the appropriation asked for by the Sections Committee, but the difficulty has been in appropriating this amount equitably among the different Sections. The Sections have undoubtedly been somewhat embarassed in their work, owing to the fact that they have not been able to know at the beginning of the year just how large an appropriation they could depend upon.

We recommend that hereafter each Section be required to submit in September an estimate of the amount that will be required from the Institute for

A.I.E.E. SECTIONS SUMMARY OF MEETINGS HELD MAY 1, 1907, TO APRIL 30, 1908*

Name of Section	Number of meetings	Original papers presented	Institute papers discussed	Visiting speakers	Attendance
Atlanta	1	1	1	—	18
Baltimore	9	6	1	3	223
Boston	6	4	4	-	631
Chicago	2	7	—	4	200
Cincinnati	8	8	—	—	79
Cleveland	4	2	—	1	176
Columbus	1	—	—	1	80
Ithaca	9	6	5	—	665
Mexico	1	—	—	—	—
Minnesota	5	1	7	—	152
Norfolk	1	—	—	—	—
Philadelphia	8	11	2	—	635
Pittsburgh	9	15	7	—	806
Pittsfield	8	8	—	2	585
San Francisco	2	—	—	—	110
Schenectady	21	19	1	9	1,200
Seattle	9	6	1	—	64
St. Louis	6	3	—	—	186
Toledo	11	9	1	1	173
Toronto	7	5	—	5	166
Urbana	10	6	8	1	1,158
Washington	3	3	—	—	69
Total	141	120	38	27	7,476

* The above summary is compiled from the reports of local secretaries to the Secretary of the Institute. Other meetings have undoubtedly been held and not reported.

A.I.E.E. BRANCHES—SUMMARY OF MEETINGS HELD MAY 1, 1907, TO APRIL 30, 1908*

Name of Branch	Number of meetings	Original papers presented	Institute papers discussed	Visiting speakers	Attendance
University of Arkansas	9	3	7	—	167
Armour Institute	15	13	—	1	280
University of Colorado	7	8	—	—	102
Iowa State College	11	8	9	—	277
Kansas State Agr. Col	4	1	1	—	—
University of Kansas	2	—	4	—	43
Lehigh University	8	8	—	—	42
Lewis Institute	3	2	—	—	400
University of Michigan	7	2	3	1	81
University of Missouri	9	1	9	—	131
University of Montana	2	—	—	—	6
Montana Agr. College	6	3	2	1	117
Penna. State College	4	—	—	—	—
Purdue University	18	12	7	—	626
Stanford University	3	3	—	—	69
Syracuse University	10	1	9	—	212
Wash. State College	4	—	4	—	54
Washington University	7	2	5	—	53
University of Wisconsin	4	3	6	—	300
Worcester Poly. Inst	10	14	—	2	1,168
Ohio State University	—	—	—	—	—
Oregon State College	—	—	—	—	—
University of Texas	—	—	—	—	—
University of Maine	—	—	—	—	—
University of Nebraska	—	—	—	—	—
University of Cincinnati	—	—	—	—	—
Total	143	84	66	5	4,128

* The above summary is compiled from the reports of local secretaries to the Secretary of the Institute. Other meeeings have undoubtedly been held and not reported.

VISITING SPEAKERS AT SECTIONS AND BRANCHES, SEASON 1908

Name	Home Address	Section	Dates
Armstrong, A. H	Schenectady.	Chicago.	
Andrews, W. S	Schenectady.	Pittsfield.	March 27, 1908.
Adams, C. A	Cambridge.	Worcester.	April 29, 1907.
Barnes, H. H., Jr	New York.	Pittsfield.	Nov. 14, 1907.
Berg, E. J	Schenectady.	Pittsfield.	Feb. 6, 1908.
Bibbins, J. R	Pittsburg.	Worcester.	Dec. 6, 1907.
Dean, W. T	Chicago.	Schenectady.	Oct. 15, 1907.
DeForest, Lee	New York.	Toledo.	Aug. 2, 1907.
Eveleth, C. E	Schenectady	Pittsfield.	Dec. 20, 1907.
Jackson, W. S	York, Pa.	Toledo.	Nov. 15, 1907.
Lincoln, P. M	Pittsburg.	Chicago.	May 24, 1907.
Mershon, Ralph D	New York.	Pittsburg.	March 14, 1908.
Moody, W. S.	Schenectady.	Pittsfield.	March 27, 1908.
Pope, Ralph W	New York.	Philadelphia.	Oct. 10, 1907.
Pope, Ralph W	New York.	Philadelphia.	Dec. 9, 1907.
Pope, Ralph W	New York	Pittsfield.	March 27, 1908.
Rushmore, D. B	Schenectady.	Pittsfield.	Nov. 2, 1907.
Rushmore, D. B	Schenectady.	Philadelphia.	Dec. 9, 1907.
Scott, Chas. F	Pittsburg.	Columbus.	Oct. 2, 1907.
Scott, Chas. F	Pittsburg.	Baltimore.	Jan. 17, 1908.
Scott, Chas. F	Pittsburg.	Ithaca.	Feb. 7, 1908.
Smith, W. N	New York.	Ithaca.	Dec 6, 1907.
Spencer, Paul	Philadelphia.	Schenectady.	Oct. 10, 1907.
Spencer, Paul	Philadelphia.	Cleveland.	Oct. 28, 1907.
Spencer, Paul	Philadelphia.	Baltimore.	Jan. 17, 1908.
Stott, Henry G	New York.	Schenectady.	Oct. 10, 1907.
Steinmetz, C. P	Schenectady.	Worcester.	April 17, 1908.
Steinmetz, C. P	Schenectady.	Chicago.	

its expenses, and that the appropriation for each Section be made in October, so that each may know definitely the amount of the appropriation and regulate its work and expenses accordingly.

This recommendation refers to the Sections, and not to the University Branches, as it is believed that the University Branches should entail little or no expense upon the Institute, and that it will be unnecessary to make them any definite appropriations.

There has been in the past year, undoubtedly, an increased amount of interest raised in the Sections by the greater number of visits which have been made to the local Sections by officers and prominent members of the Institute. The records of the Institute would indicate that between 40 and 50 such visits have been made, and the Sections Committee would express its appreciation to the different men who have contributed so much to the interest of the local meetings.

Respectfully submitted,

PAUL SPENCER,

Sections Committee Chairman.

Presentation to the Institution of Electrical Engineers

At a meeting of the Board of Directors of the American Institute of Electrical Engineers, September 28, 1906, and in accordance with the action of the board, President Sheldon appointed a committee consisting of John W. Lieb, Jr., Schuyler Skaats Wheeler, and Ralph W. Pope, to prepare a suitable testimonial for presentation to the Institution of Electrical Engineers in acknowledgment of courtesies to the representatives of the American Institute of Electrical Engineers who participated in the Circular Tour through Great Britain in July, 1906. The committee decided that the testimonial should be made in the form of a bronze bust of Benjamin Franklin, bearing a suitable inscription, and mounted on a mahogany pedestal. This was subsequently forwarded to Mr. Horace F. Parshall, Local Honorary Secretary of the Institute for Great Britain, by whom it was presented to the Institution of Electrical Engineers, at the general meeting held at London on April 30,

1908. The following is an extract from the official proceedings on that occasion.

EXTRACT FROM THE PROCEEDINGS OF THE INSTITUTION OF ELECTRICAL ENGINEERS AT THEIR GENERAL MEETING OF APRIL 30, 1908.

PRESENTATION OF A BUST OF BENJAMIN FRANKLIN BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

THE PRESIDENT, COLONEL R. E. CROMPTON, C.B.: I understand that we have among us an ambassador from the American Institute of Electrical Engineers, who is charged with the performance of a duty, and I now have the pleasure to call upon him to perform it.

H. F. PARSHALL: Mr. President and members of the Institution of Electrical Engineers: I have the honor and pleasure to present on behalf of the American Institute of Electrical Engineers a souvenir of their happy remembrances of a trip to this island about a year and a half ago. They were so cordially received by the members of this Institution that a lasting impression was made upon their minds, hence the desire to emphasize particularly in a permanent way, their appreciation of the kindness and hospitality which they had received at the hands of their brother engineers in Great Britain. Although the number of members of the American Institute that were able to come abroad was but a small fraction of the whole, the account they gave of their reception was so cordially received by the Institute that this tribute comes forward by the unanimous wish of the members of the American Institute. It may not be generally known that this presentation would have been made on the inauguration of Lord Kelvin as president of this Institution. This was thought to be the most auspicious occasion that could be selected to emphasize the friendship which exists between the two institutions, in fact, it was felt that this was the most auspicious occasion that could happen in the electrical engineering world, since nothing could so far advance the position of the electrical engineer as the fact that Lord Kelvin at his great age and with his great position was willing to preside over this Institution as an expression of his desire to further the interests of electrical engineering.

Alas, the occasion so much hoped for was not to be! It is consoling, however, to think that Lord Kelvin, accompanied by Lady Kelvin, had seen this statue and had expressed his appreciation and admiration of it; and it certainly adds greatly to the value of it to know that it was seen by Lord Kelvin, who strongly approved of the sentiment by which the gift was prompted. The letter from Mr. Pope, Secretary of the American Institute, asking me to make this presentation, stated that the subject is Benjamin Franklin. It appears to me that the selection is an extremely happy one, since Benjamin Franklin is by common consent the greatest natural philosopher born and bred on American soil. Kelvin, as we are all most happy and proud to admit, was the greatest natural philosopher and scientist associated with the advancement of electrical science yet born to the world. Franklin's insight into nature came from a purely natural genius and the discoveries he made were intuitive. Kelvin had the same natural genius, but he had the additional advantage of great mathematical powers of analysis. While the investigation of electrical phenomena by Franklin was but one department of a busy life, and became more of a pastime given out of such time as could be spared from attending to matters of state, since he was perhaps greater as a statesman than as a natural philospher, Kelvin's whole life was devoted to science and without intermission he successively enriched and perfected knowledge on all branches of physical science. It has been frequently stated that for all practical purposes Franklin was an Englishman. That his origin and methods were English there can be no dispute nor wish to dispute so far as the Institute I am speaking for is concerned, and this same characteristic applies to most of the names that have given America her position in connection with the development of electrical science. I refer to such names as Henry, Farmer, Morse, Bell, Edison, and Elihu Thomson.

It is with especial pleasure that I make this presentation, since I have the honor of being a Member of both the American and British Institutions, and having now resided so many years in this country, any event that may emphasize and strengthen the friendship between the two leading bodies of electrical engineers is especially welcome to me. Mr. President and members, of the Institution of Electrical Engineers, I now respectfully request you to accept this bust of Benjamin Franklin as a token of the sincere friendship and esteem of your brother engineers in America, the president and members of the American Institute of Electrical Engineers.

THE PRESIDENT: Mr. Parshall, and other members of the American Institute of Electrical Engineers who are present. On behalf of the Council and the members of our Institution, I wish to say that we very highly appreciate this beautiful gift to us from our American friends, in courteous recognition of their reception and entertainment on the memorable occasion when it was our great privilege to receive them as the honored guests of the Institution. I have also to thank you, Mr. Parshall, for the appropriate and kindly words you have used in referring to our late President, Lord Kelvin. I understand from what you have said that both he and Lady Kelvin saw and greatly admired the bust of Benjamin Franklin, which you have now presented to the Institution, and we deeply deplore the sad event which prevented the acceptance of the bust by him as our president at the opening of the session. It now remains for me to accept with gratitude, in the name of our members, this representation of your illustrious countryman, that great investigator and statesman, Benjamin Franklin. I beg that you will bear to your president and members in America a message from us expressive of the warm feeling which we have for them, and that we shall ever entertain the liveliest recollection of their kindly reception of us when we visited the United States, at the time of the St. Louis Exhibition in 1904. We feel we were only able to make but a poor return to them when they honored us, two years ago, by becoming our guests in turn, but we hope we may be able to receive them again at some future time, and that there will be many opportunities of fostering the cordial relationship and warm feeling which at present exists between the two Institutions, making them practically one as regards scientific thought and attainment. The gift of to-day forms an additional tie between our two great kindred societies.

I have now to propose: " That the most cordial thanks of the Institution of Electrical Engineers be, and are hereby expressed, to the American Institute of Electrical Engineers for their great kindness and courtesy in presenting to us, through Mr. H. F. Parshall, their honorary secretary for Great Britain, the magnificent bust of their great countryman, pioneer and investigator in electrical science, Benjamin Franklin. The gift will ever be treasured and preserved by us in token of the cordial friendship existing between the sister Electrical Engineering Societies of America and Great Britiain."

The resolution was carried with acclamation.

An interesting example of international academic courtesy took place at the University of Liverpool on July 2, when that University, acting for Lehigh University of Bethlehem, Pa., conferred the degree of Master of Science on Mr. Horace F. Parshall. Mr. Parshall was graduated at Lehigh University, in the electrical engineering course, in 1887.

Sections and Branches

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

A meeting was held in the engineering rooms on May 14, C. R. Morey presiding, with an attendance of 13. Mr. Morey read a paper on " Lightning Protective Apparatus." He discussed atmospheric conditions making lightning protection necessary. The effect of lightning discharge was pointed out and similar effects produced in switching were also shown. The theory of the lightning-arrester and its component parts was taken up together with their location to afford the most efficient protection. Mr. Morey described the more important types of arresters from the earliest forms to the most recent. The operation of each was fully explained. A few foreign types of arresters were discussed briefly. The multigap and electrolytic arresters were considered in detail. A short discussion followed the reading of this paper.

A meeting was held in the physics lecture room on May 21, 1908, T. C. Oehne, Jr., presiding, with an attendance of 32. Lieutenant W. F. Sims, past assistant engineer of the Illinois naval reserves, read a paper on " Some Features of the Electrical and Mechanical Equipment of the U. S. Navy."

Among the mechanical features taken up were the construction of ship, water, sewerage, heating, and refrigerating systems. Water-tube boilers were discussed and their availability for this class of work pointed out because of smaller units, less weight per boiler horse power, and higher allowable pressures. The necessity for mechanical draft on account of insufficient height of stacks to allow for natural draft, was discussed, together with the methods of obtaining it. The kinds of engines were considered and their peculiarity for the special class of work discussed. The very rigid requirements for the electrical installations of first-class battle ships because of the steel construction and exposure to moisture was pointed out. Amongst other things it was shown that a special circuit is provided for battle service. This circuit carries only such lighting as is necessary in action, day or night. All feeders as far as possible are run below the protective deck or behind armor. Eighty volts was standard until recently. Now 125-volt installations are standard, due to the rapid increase in the motor load. In the later ships fully 80 per cent. of the generating capacity is used for power purposes. In ships of the Connecticut type, about 800 kw. is provided in eight 100 kw. units direct connected to high speed vertical cross compound engines. The Connecticut, for example, carries 213 motors ranging from 0.25 to 80 h.p. in addition to 73 portable fan motors. An interesting discussion followed the reading of this paper.

A meeting was held in the engineering rooms on May 27, T. C. Oehne, Jr., presiding, with an attendance of 24. Professor John E. Snow read a paper on " Machine Tool Driving."

In the introduction to his paper, Professor Snow contrasted conditions under the old method of driving with engine and counter-shafts with those now existing with motor drive, discussing improved efficiency in both machine operation and shop output. The subject of group or individual drive was treated along the line of size of motor and kind of system in use. The characteristics of the various types of motors both alternating-current and direct current, were discussed in their bearing on this class of work. An attempt was made to find out the tendency of the times in regard to the use of the newer types of motors such as the inter-pole and various others. The subject of speed limits for motors used in machine tool work was discussed and deductions drawn from tabulated data obtained from machine tool manufacturers. A number of letters were read, from both manufacturers and engineers prominent in the installation of manufacturing and repair shops. The paper was illustrated with lantern slides showing typical methods of driving such machinery by motors. An interesting discussion followed.

———

A special meeting was held May 28 for the election of officers for the ensuing year. The officers elected are as follows: for vice-chairman, Tracy W. Simpson; for recording secretary and treasurer, F. C. Zanzig.

ATLANTA SECTION

The Atlanta Section held its regular meeting on the first Tuesday in June in Room 1331 Candler Building, Atlanta, Ga. The meeting was presided over by Mr. J. H. Finney. On account of the meeting date falling on election day the attendance was smaller than usual, but the discussion on lightning protectors was participated in by a number of members and the meeting was thoroughly enjoyed by all present.

BALTIMORE SECTION

The Baltimore Section held a meeting at Johns Hopkins University, June 12, 1908, Professor J. B. Whitehead presiding, with a total attendance of 55 members and visitors. Mr. W. A. Young chairman of the committee on nominations, reported the following ticket: for chairman, J. B. Whitehead; secretary, Charles G. Edwards; executive committee, Messrs. Douglass Burnett, P. O. Keilholtz, Charles E. Phelps, Jr., L. M. Potts, Carroll H. Thomas. The nominations were approved and the above members were elected as officers for the ensuing year. The paper of the evening, "From Steam to Electricity on a Single Track Railroad," was read by Dr. J. B. Whitehead, and was most interesting, the subject being treated in a masterly way.

BOSTON SECTION.

A meeting of the Boston Section was held in the auditorium of the Edison Building on May 20, 1908. The meeting was called to order by Chairman Puffer at 8.05 p.m. The Chair stated that Messrs. Elden, Vaughan and Shaad, had been appointed a nominating committee, who reported a list of nominees as officers for the ensuing year, as follows: chairman, A. E. Kennelly; vice-chairman, D. C. Jackson; secretary-treasurer, Albert L. Pearson; executive committee, Messrs. Corning, Gibbs, Shaad, Vaughan, and Wiard.

It was voted that the secretary be requested to cast one ballot for the officers above named, which was done, and they were declared elected. Professor Puffer called upon Mr. Vaughan, who presented a paper on "Comparative Tests of Lightning Protection Devices on the Taylor's Falls Transmission System." Mr. Neall then presented a paper on "Studies in Lightning Performance, Season of 1907." A general discussion followed. There were about 60 members present. Adjourned at 9.40 p.m.

CHICAGO SECTION

A meeting was held on June 5, 1908, in the rooms of the Western Society of Engineers. Mr. W. L. Abbott presided. Mr. R. F. Schuchardt read a paper on "Recent Developments in Protective Features of a Large High-Tension Underground System."

The experience of the Commonwealth Edison Co., which led to the development of an extremely simple system of protection was described, and some cardinal principles were laid down regarding the application and installation of protective devices. Sectional operation, the grounded neutral, selective relay setting, and relay experiences were dealt with. In view of the extreme importance of this subject to the larger central station companies, the local committee invited discussions and comparison of experience from engineers of some of the larger companies. The discussions thus received from New York, Brooklyn, Boston, St. Louis, and Milwaukee, made the evening an instructive and valuable experience meeting. The further local discussions by Messrs. Junkersfeld, Abbott, Wiler, PenDell, Roper, Schuchardt, and others, brought out considerable operating information. Altogether, from an "electricity transmission and distribution" viewpoint the meeting was one of the most valuable ever held in Chicago.

UNIVERSITY OF COLORADO BRANCH

A meeting was held in the engineering building on May 6, L. R. Handley presiding, with an attendance of 28. Mr. L. M. McBride, electrical engineer for the Cary & Fielding Mining Machinery Company of Denver, delivered an address on "The Cost and Construction of Small Switchboards." He took up the cost of various kinds of boards and methods of assembling, also the practical difficulties met with in installation and maintenance.

Several amendments to the constitution were proposed, after which the meeting was adjourned.

A meeting was held on May 20, L. R. Handley presiding, with an attendance of 28. The amendments which were proposed at the previous meeting were taken up and adopted. It was moved that the constitution be typewritten. The following named officers were elected for the ensuing year: H. H. Watters, chairman; L. D. Jones, secretary; G. W. Sorenson, treasurer; J. S. De Remer, chairman of the program committee, and A. P. Sunnergren, committee man. Professor H. S. Evans gave a short talk on engineering in general, after which the installation of officers took place.

IOWA STATE COLLEGE BRANCH

March 25, 1908—35 members and visitors attended this meeting, which was presided over by Adolph Shane. The chairman of the social committee made a report. He showed that an assessment of 50 cents per member was necessary in order to make the social of April 23 a success. Assessment was accordingly authorized and it was further voted that the invitations should be issued the same as for the social meeting of last term. There were two papers presented. One by Mr. Moore was an abstract of two articles from the March, 1908, number of the *Engineering Magazine*. The first article was by Mr. H. M. Horton on "The Management of Production in a Great Works." This took in the organization, plan and system of the Westinghouse Electric and Manufacturing Company. The other paper was by G. F. Stratton on "Labor Cost Distribution at the General Electric Shops." This outlined the methods developed and the results secured. Discussion by Messrs. Van Deventer, H. J. Cooper, A. W. Thompson, M. W. Pullen, and Adolph Shane.

The second paper of the evening was on "Electrolysis" by Ganz in the *Electrical Age* of February, and abstracted by Mr. Sackrison. This paper cleared up some of the obscure points in the methods used for the detection and measurement of the earth currents. The paper indicated how easily one might be led astray if a common though incorrect method were used.

The meeting of April 1 passed without any particular event in spite of the date, excepting that Professor Fish, the chairman, did not materialize. However, 23 Institute members and 7 visitors decided to hold the meeting in the usual way. Adolph Shane, the secretary, presiding in the absence of the chairman. Mr. Van Deventer reviewed Messrs. Stillwell and Putnam's paper on the "Electric Haulage of Canal Boats," which appeared in the March PROCEEDINGS. The discussion by Messrs. Pullen, Garner, Van Deventer, Meeker, Halpenny and Shane brought out the one fact that in general electrification of our canal system might probably be not far different in the ultimate problem than constructing an electric railway along the same highway. That is, we are approaching the electric railway idea in spite of the waterway at the disposal of the community, and hence, excepting for some special cases, the expense of the electrification, as in a railway, enters and the cheapness and simplicity of mule power disappears. Mention was made of the discussion by Dr. Steinmetz hinting at this very point.

———

April 15—24 members of the Branch and 11 visitors attended this meeting, presided over by F. A. Fish. The membership question was brought up and in this connection Mr. Pullen advised the reading of Mr. Rushmore's paper on membership. Mr. Dewey made a report of the social committee about the social meeting to be held April 22. The program for the event was discussed at some length. It was finally decided to give the social committee full sway. The first paper was an abstract of " Protection of Electrical Apparatus from Lightning and Similar Disturbances " appearing in the *Electric Journal* and abstracted by Mr. Ross Rudd. It was shown that some of the effective methods of overcoming static disturbances are: overhead grounded conductor, multigap lightning arrester, electrolytic arrester, and spark gap. In the discussion, the chairman brought out the fact that the problem of lightning protection could not be said to be solved yet. Further, it was brought out that the matter of grounds was important and that the methods used for grounding were not entirely above criticism. The next paper on " Porcelain " was abstracted from the *General Electric Review* by Mr. Kreul. The dry and wet process of porcelain manufacture for electrical purposes was discussed and the merits of each brought out.

———

The second social meeting of the Iowa State College Branch was held April 29 (postponed from April 22). This proved to be if anything more successful than the meeting of like nature held last fall. A general good time was evident and interest did not lag from the beginning to the end. There were 73 present. The log of this meeting shows that the various members of the Branch are saturated electrically and magnetically; some of them possess attributes commonly supposed to cling close to alternating-current circuits.

During intervals Professor Fish had his phonograph talking and singing, and this requires further word. There are many talking machines of different kinds on the market, good, bad and indifferent. This one is of the first class. Selections as solos, quartettes and sextets from the great singers of the world were reproduced so realistically that applause was spontaneous, and from an artistic view-point the oft-derided talking machine was surely vindicated.

———

May 6—This meeting was given over chiefly for the election of officers for the fall term of 1908. There were 25 members present. The several committees made reports. It was decided to have the A.I.E.E. Members and Associates of the Branch meet the deficit in the treasury. It was moved and cordially seconded that a vote of thanks be extended the social committee for the excellent way in which the program of April 29 was carried to a conclusion. It was carried unanimously. The members then proceeded to the election of the officers. Professor F. A. Fish was re-elected chairman and Professor Adolph Shane was re-elected secretary. The results of the election of members of the executive committee gave Messrs. Frank K. Shuff, H. W. Wagner, and George A. Mills a majority vote and they were declared elected. Messrs. McElyea, Bek, and King receiving majority votes were declared elected as members of the social committee. It was moved by Mr. Pullen and seconded by Mr. Shane that the increase of membership committee be continued next term and that the two juniors at present on the committee be continued thereon and that the Chair appoint at his leisure members to fill the three vacancies caused by those departing. Carried.

The above meeting closed the 1907-08 year of the Iowa State College Branch meetings. The interest taken in the organization by the members proved very gratifying and even an increased success is confidently predicted for the coming year.

KANSAS UNIVERSITY BRANCH

A meeting was held on May 28, 1908, M. E. Rice presiding, with an attendance of 31. On this occasion the members of the Branch were given an unusually good program, after which refreshments were served and a social session enjoyed by all. Professor E. F. Stimpson gave a lecture on the singing and talking arc, and illustrated his lecture by actual experiments showing the effects of varying the inductance and capacity upon the tones emitted. Mr. L. E. Mason, manager of the Missouri and Kansas Telephone Co. in Lawrence, then gave an address on " Present Practical Uses of Wireless Telephony." He first gave its early history and then described the present methods and uses to which it is applied.

LOS ANGELES SECTION

The first meeting of the Los Angeles Section of the American Institute of Electrical Engineers was held at the Hotel Hayward, Los Angeles, California, June 16, 1908, at 6:30 p.m. There were present eighteen members and fifty-one visitors. An informal dinner preceded the business session. Mr. C. W. Koiner and Mr. J. E. Macdonald were unanimously elected temporary chairman and secretary respectively.

A preliminary form of by-laws was submitted and adopted. An executive committee of seven was elected as follows: C. A. Copeland, C. W. Koiner, J. A. Lighthipe, J. E. Macdonald, T. A. Panter, E. Y. Porter and E. Woodbury. From this number, the chairman, secretary, and assistant secretary will be elected by mail ballot.

Many of the non-members present, prominent in the electrical field in Southern California, expressed a desire to become affiliated with the Institute and the outlook is exceedingly promising for an active and enthusiastic Section.

MONTANA AGRICULTURAL COLLEGE BRANCH

The regular May meeting was held in the electrical lecture room, C. M. Fisher presiding, attendance 22. Mr. F. S. Lorentz gave a talk on the Westinghouse apprenticeship course and Mr. W. Griffith told of his experience as an operator at the Hauserlake power plant.

At a special meeting held May 22, the following officers were elected for the coming year: chairman, B. S. Hind; secretary, J. A. Thaler; treasurer, A. S. Brown.

NORFOLK SECTION

A meeting was held in the assembly rooms of the Board of Trade on June 12, temporary chairman, R. R. Grant, presiding, with an attendance of 12. Mr. Grant stated that the meeting had been called to receive the report of the organization committee. Mr. Stanbrough presented the report, which consisted mainly of the following By-laws, which were adopted.

BY-LAWS OF THE NORFOLK SECTION

1. *Name.* Under the Constitution of the American Institute of Electrical Engineers and pursuant to authorization of its Board of Directors March 13, 1908, this Norfolk Section is organized.

2. *Membership.* The membership of this Section shall consist of Members and Local Members.

(a) Members and Associates of the Institute residing in Norfolk and vicinity shall be corporate members of the Section.

(b) Local Members shall be persons engaged in electrical work in this vicinity.

They shall be entitled to enjoy all the privileges of the Section with the exception of voting for and holding office.

Application for Local Membership shall be made to the secretary. At the next regular meeting of the Section, the secretary shall read the name of such applicants and any member objecting to their election shall communicate to the secretary at the close of the meeting. The secretary shall submit his recommendations to the executive committee for ratification.

3. *Dues.* Corporate members shall be exempt from dues. Special assessments may be levied by a majority vote of those present at any regular meeting.

Local Members shall pay $3.00 per annum. The fiscal year shall commence with the first meeting in the fall. Local Members elected prior to January 1, shall pay the full dues for that year, after January 1 they shall pay $2.00.

4. *Quorum.* Seven corporate members shall constitute a quorum.

5. *Meetings.* The Section shall hold regular monthly meetings from October to June, for the presentation of papers and discussion on electricity and the allied arts and sciences. The June meeting shall be an annual meeting at which the Section officers for the following year shall be elected. The monthly meetings shall be held the week following the New York meeting.

6. *Officers.* The management of the Section shall be in the hands of an executive committee consisting of a chairman, vice-chairman, local secretary, and three others, one of whom shall reside at Newport News and be elected by the members from that city. Corporate members of the Section shall vote by ballot for the executive committee. The officers of the executive committee shall constitute the officers of the Section.

7. *Government.* The government of the Section, the procedure therein, the duties of the officers shall be in accordance with the Constitution and By-laws of the Institute, the reports of the Sections Committee of the Institute submitted December 20, 1907, and published in the February PROCEEDINGS, the By-laws of this Section and Roberts Rules of Order, in the order named.

8. *Amendments.* These By-laws may be amended by a majority vote of the corporate members present at any regular business meeting held after notice has been given that the amendment is to be considered.

The Section elected the following executive committee: D. G. Stanbrough, chairman; R. A. Smith, vice-chairman: R. R. Grant, secretary; C. W. Bradley and A. H. Apperson, and one member to be elected from Newport News.

Mr. Stanbrough, upon taking the chair, appointed the following membership committee: W. C. Dean, W. R. Cook, I. A. Blumgart, H. R. Palmer. The Section then adjourned to meet again the second week in September.

OREGON AGRICULTURAL COLLEGE BRANCH

A meeting was held in Mechanical Hall on May 27, C. V. Hawley presiding, with an attendance of 36. Engineering education was discussed by Professor Gardner, Messrs. C. Christianson, W. R. Baker, R. Wall, and E. C. Wiggen. The next meeting of the Branch will be held early in October.

PHILADELPHIA SECTION

A meeting was held at Boothby's restaurant on June 8, J. F. Stevens presiding, with an attendance of 95. The committee reported on the Toronto resolution regarding a new grade of membership, and Mr. Hering, the chairman, read a new resolution which was drawn by the committee. After considerable discussion the motion to adopt the resolution was lost. The following named officers were elected: president, Paul Spencer; managers, H. C. Snook, W. E. S. Temple, Geo. Ross Green; secretary-treasurer, H. F. Sanville; assistant secretary, L. J. Costa; Mr. Eglin made a short address on the coming Atlantic City convention.

SAN FRANCISCO SECTION

The February meeting of this Section was held on February 28 in the hall of the California Gas and Electric Corporation's Building; attendance 110. The chairman of the Section, Mr. A. M. Hunt, presided. Mr. F. G. Baum presented a paper on " A High-Head Turbine Unit." The turbine referred to is installed in the Centerville station of the California Gas and Electric Corporation, and is operating under a 600 ft. head.

Owing to Mr. Baum's absence, the paper was read by Mr. P. M. Downing and further explained in detail by means of lantern slides. Mr. W. A. Doble discussed the paper in detail, claiming that the ultimate head under which a Francis type turbine can be economically and successfully operated is limited by approximately 200 ft. Mr. L. Jorgensen brought out the point that variations in head affect the turbine efficiency less than the water wheel. The paper was further discussed by Messrs. Lee, Wise, Bowie, Babcock, Hutton, and Adams.

At the conclusion of this discussion, there was an informal talk on " Transformer Oil ", in which the following members took part, Messrs. Lighthipe, Lee, Downing, Babcock, Meredith, Bowie, Holberton, Van Norden, and Adams.

Before the meeting adjourned, the chairman, Mr. A. M. Hunt, announced that at the March meeting a paper would be presented on " Single Phase Traction " and discussed by several members who would, in the meantime, visit the installation of the Vallejo, Benicia and Napa Valley Railroad.

At a meeting of this Section, on May 29, 1908, A. J. Bowie, Jr., presented a paper entitled " Horn Type Arresters and Automatic Circuit-Breaker." This paper is printed in full in the *Journal of Electricity, Power and Gas*, of June 20, 1908, and the discussion on it in the same journal of June 27, 1908.

TOLEDO SECTION

A meeting was held in the Builder's Exchange on June 5, C. R. McKay presiding, with an attendance of 43. The minutes of the April and May meetings were read and approved. A letter from Public Librarian Sewell was read, and in accordance therewith a motion was made and carried that the chairman appoint a committee to wait upon Councilman Fielbach in the interests of a larger allotment for the Toledo Public Library. Secretary Pope's letter of May 1, concerning a delegate to attend the convention at Atlantic City, was read. Mr. McKay announced his inability to attend, and George E. Kirk was elected alternate. Mr. J. M. S. Waring of Chicago delivered an address on the uses of storage batteries. Among the matters considered by Mr. Waring were that in large plants where there are heavy loads of short duration, the economy in operation of installing and running less machinery than maximum load requirement, by the aid of storage batteries, is considerable. Again the power user whose consumption varies widely, may in many instances use storage cells to make his needs more uniform with a saving in current cost. In smaller plants handling power and lighting, when the power demand fluctuates considerably, as in elevator service, a most decided improvement in lighting may be brought about by using electric storage batteries.

A new application, recently perfected by Mr. Woodbridge, was touched upon, whereby a split pole converter may be so connected up in alternating-current service with storage cells, that the cells may act as a flywheel to keep down the peak of heavy load demands on generator even more accurately than in present direct-current work

---

A special meeting of Toledo Section was held June 25, 1908, making a trip to Detroit for the entire day to attend the convention of the American Society of Mechanical Engineers. Through the courtesy of the Toledo Railway & Light Company, the private car Toledo was obtained for the occasion. By previous arrangement with the Detroit Convention Committee, the privileges of the meeting were extended to Toledo Section as guests of its secretary, a member of the A. S. M. E.

In the forenoon, the launching of the Daniel B. Meacham at the Ecorse shipyards of the Great Lakes Engineering Works was witnessed. In the afternoon, besides the regular A. S. M. E. session, there was a simultaneous meeting of the Gas Power Section, where papers of considerable interest to many of Toledo Section were read and discussed.

The day was ideal for the quick trolley excursion, as well as for the meetings. The carload of section members enjoyed the outing.

WASHINGTON SECTION

A meeting was held in Hubbard Memorial Hall on April 21, David S. Carll presiding. Mr. C. D. Haskins of Schenectady gave an illustrated discourse on "Recent Developments in Electric Lighting."

———

A meeting was held in George Washington University on May 20, Paul G. Burton presiding, with an attendance of 12. It was the annual meeting at which the election of officers takes place.

The secretary made a report showing that during the year three meetings had been held, at which papers were presented. On three other months, meetings were held jointly with other associations; and in the month of March no meeting was held, owing to the large number of scientific and professional societies in Washington, who hold regular meetings at various intervals.

It has been a question on the part of some members of the local Section as to whether an attempt should be made to hold regular monthly meetings. A consensus of opinion among the members generally is that the Section organization ought to be retained. After a lengthy discussion of the matter of holding meetings, it was decided to proceed next year as has been done in the past by holding eight meetings in the course of the year. An executive committee was elected, composed of men who were in favor of keeping up regular meetings.

Motion was made and seconded that the delegate to the Convention be instructed to recommend to the chairman and committee of local organizations that a certain proportion of the dues paid in by members should be set apart for maintenance of local Sections. After a great deal of discussion, the motion was finally passed. The annual election was then held, which resulted in the election of Philander Betts, chairman for the coming year; Louis D. Bliss, secretary. The remaining members of the executive committee are: John H. Hanna, Paul G. Burton, and Mr. H. C. Eddy.

Mr. Paul G. Burton was elected alternate, in case the chairman of the Section should be unable to attend the Convention at Atlantic City, June 29, 1908.

WASHINGTON UNIVERSITY BRANCH

A meeting of the Washington University Branch was held at 2:10 p.m. on March 25, 1908, in room 202, Cupple's Hall II, by Chairman Burnet. Attendance, members 12; visitors 8. Professor Langsdorf read a most interesting paper on "Engineering Education". He attributed most of the trouble that technical schools experience with first-year students to lack of thoroughness in preparatory school training. He believes that too much time is spent on educational fads, to the detriment of drill and discipline in fundamental subjects. Attention was called to the fact that it is becoming more and more necessary for the modern engineer to combine general education and culture with technical training.

A lively discussion followed the conclusion of the paper and Mr. Burnet suggested an arrangement of the courses in the electrical engineering department of the university that offered several advantages.

———

Another meeting of the Washington University Branch was held at 2:25 p.m. on April 8, 1908, in room 202, Cupple's Hall II, Chairman Burnet presiding. The attendance was very small, only 10 being present. The minutes of previous meeting were read and approved. Mr. Tyler's paper was an abstract of the Institute paper by Mr. A. H. Armstrong on "The Comparative Performance of Steam and Electric Locomotives", which appeared in the PROCEEDINGS, October, 1907. The limitations of the steam locomotive, especially as regarding efficiency and economy at high speeds and under over-load, were pointed out. The advantage of the electric tractor under these as well as other conditions was demonstrated and numerous other points of interest and importance regarding the subject were brought out. A brief period of inquiry and discussion followed the paper.

Another meeting of this Branch was held on May 13, 1908. Mr. Toeppen gave the results of part of his thesis work on " Fatigue of Insulators." He also described the apparatus used and the methods employed in his investigations.

Messrs. Tyler and Burnet described their thesis work, " The Design and Construction of a 150,000-volt Transformer." Mr. Burnet took up the details of design and Mr. Tyler described the construction. The many difficulties that arose during the process of construction and the ways of avoiding and overcoming them made their talk very interesting. After a short period of inquiry and discussion the meeting adjourned at 4:10 p.m.

The meeting of the Branch on May 26, 1908, was called to order at 9:00 p.m. in the Sigma Chi Fraternity Rooms by Chairman Burnet. Attendance, members, 15. The reading of minutes was omitted and we proceeded to the election of the chairman and vice-chairman for the year 1908-9. The result of the election was as follows: chairman, C. M. Duncan; vice-chairman, W. D. Barnes. The secretary is chosen in October from the Junior Class.

Professor Langsdorf spoke in a most interesting manner on " The Patent Situation in the United States ". He spoke in turn of the abuses of the patent laws, stated the defects in the laws that made abuses possible, and suggested changes that would tend to reduce the abuse of patent rights. The superior points of German patent laws were referred to several times. It was also stated that the Patent Office in this country was not given by the government the attention and support that its importance called for.

At the conclusion of Professor Langsdorf's talk Mr. Lamke gave us some reminiscences of his university days at Michigan.

Refreshments and cigars together with several good stories occupied the time until midnight at which time the Branch adjourned till October, 1908.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before September 11, 1908.

7700	Darrall, S. S., Iquique, Chili, S. A.
7701	Ross, E. J., Jr., Little Silver, N. J.
7702	Zetherlund, C. A., Baramulla, Kashmir, India.
7703	Dobson, A. E., Waratah, Tasmania
7704	Millar, H. M., Wellington, N. Z.
7705	Tryon, Allan C., Maumee, O.
7706	Fahy, J. T., Wellington, N. Z.
7707	Gupta, B. C., London, Eng.
7708	Bossert, C. P., Milwaukee, Wis.
7709	Hall, W. D., Port Huron, Mich.
7710	Ogle, Thomas B., Norfolk, Va.
7711	Rosok, I. A., Bisbee, Arizona.
7712	Sutherland, K. W., Adelaide, Aus.
7713	Batchelder, W. O., Salem, Mass.
7714	Gettrust, John, So. Norwood, O.
7715	Servos, John, Toronto, Ontario.
7716	Watts, George E., Atlanta, Ga.
7717	Fellechner, F. G., Bridgeport, Ct.
7718	Peeples, Ben, Memphis, Tenn.
7719	Ballard, A. W., Los Angeles, Cal.
7720	Lasar, F. J., St. Louis, Mo.
7721	Reeve, J. W., Jr., Lake City, Fla.
7722	Sawtelle, E. M., Hale, Cheshire, Eng.
7723	Sprague, S., Winthrop, Mass.
7724	Kirschberg, H., Altoona, Pa.
7725	Batchelder, C. K., Colorado Spgs.
7726	Benziger, J. U., Bahia, Brazil, S.A.
7727	Cursset, P. D., Sao Paula, Brazil.

7728 Daggett, P. H., Neponset, Mass.
7729 Eyre, Richard, N. Y. City.
7730 Weller, H. F., Los Angeles, Cal.
7731 Scattergood, E. F., Pasadena, Cal.
7732 Sandford, J. A., Jr., New Lexington, O.
7733 Rojahn, E. E., Dallastown, Pa.
7734 Swann, Theodore, Bristol, Tenn.
7735 Kemp, C. G. R., Brazil, S. A.
7736 Watson, Lionel, Toronto, Ont.
7737 Kensit, H. E. M., Toronto, Ont.
7738 Hilleary, O., Los Angeles, Cal.
7739 Stahl, Nicholas, Pittsburg, Pa.
7740 MacDonald, G. W., Los Angeles.
7741 Pyle, C. G., Los Angeles, Cal.
7742 Möller, N. A., Mexico City, Mex.
7743 Smith, W. B., Los Angeles, Cal.
7744 Kean, Alonzo, Los Angeles, Cal.
7745 Jackson, C. H., Los Angeles, Cal.
7746 Beals, F. H., Los Angeles, Cal.
7747 Walton, F. P., Los Angeles, Cal.
7748 Boxall, W. L., Los Angeles, Cal.
7749 Darnell, W. H., Los Angeles, Cal.
7750 Manahan, R. H., Los Angeles, Cal.
7751 Roome, W. G., Los Angeles, Cal.
7752 Seaman, J. H., Tropico, Cal.
7753 Kelman, J. N., Los Angeles, Cal.
7754 Geer, F. H., Los Angeles, Cal.
7755 Cox, J. H., Los Angeles, Cal.
7756 Ballard, A. H., Los Angeles, Cal.
7757 Glasgow, A. S., Los Angeles, Cal.
7758 Wintersgill, H. L., Los Angeles.
7759 Socci, J. B., Mexico City, Mex.
7760 Gaylord, R. H., Pasadena, Cal.
7761 Shortall, O. R., Philadelphia, Pa.
7762 Grant, W. M., San Francisco, Cal.
7763 Tate, J. V. E., Kankahalli, Mysore.
7764 Farrand, A. C., Atlantic City, N. J.
7765 Young, H. P., Atlantic City, N. J.
7766 Wilson, J. L., Brazil, S. A.
7767 Braun, C. F., San Francisco, Cal.
7768 Reed, Robert R., Washington, Pa.
7769 Twining, H. LaV., Los Angeles.
7770 Thompson, D. B., Schenectady.
7771 Brill, O. C., San Francisco, Cal.
7772 Brandenburg, T., Pachuca, Hidalgo, Mex.
7773 Chesrown, E., Pittsburg, Pa.
7774 Gilbert, L. D., Los Angeles, Cal.
7775 Foster, F. F., Los Angeles, Cal.
7776 Campbell, C. H., Los Angeles, Cal.
7777 Myers, A. S., Los Angeles, Cal.
7778 Foulkes, T., Los Angeles, Cal.
7779 Hoag, W. S., Los Angeles, Cal.
7780 Carleton, L. F., Davidson, N. C.
7781 Darling, G. F., Minneapolis, Minn.
7782 Hastin, F. W., Piermont, N. Y.
7783 Falk, H. S., Milwaukee, Wis.
7784 Ingham, W. F., Ponce, P. R.
7785 Woehler, W. L., Goldfield, Nev.
7786 Noble, J. P., Oklahoma City, Okla.
7787 Francis, I. J., Los Angeles, Cal.
7788 Moore, N. S., Morton Park, Ill.
7789 McKibbin, R. H., Loomis, Wash.
7790 Lidders, A. H., Los Angeles, Cal.
7791 Dalton, W., Philadelphia, Pa.
7792 Hughes, R. J., San Francisco, Cal.
7793 Halloran, A. H., San Francisco, Cal.
7794 Franz, W. G., Cincinnati, O.

Total, 95.

Personal

THE ENGINEERS' CLUB of Philadelphia has removed to 1317 Spruce street, Philadelphia, Pa.

V. KARAPETOFF, formerly assistant professor, has been made a professor of electrical engineering at Cornell University.

MR. W. C. WAGNER is at present chief electrical engineer of the N. W. Improvement Company, at Roslyn, Washington.

MR. CHARLES S. POWELL has removed his office from No. 12 Broadway, to the City Investing Building, 165 Broadway, New York.

MR. ALEXANDER M. GRAY, designing engineer with Allis-Chalmers Company, has been transferred from Cincinnati to Milwaukee.

MR. OSCAR FRIEDRICH, has recently accepted a position with Pattison Brothers, consulting engineers, Broadway and Fifth Avenue, New York.

MR. RODMAN GILDER has been elected secretary of the Crocker-Wheeler Company, Ampere, New Jersey, manufacturers and electrical engineers.

Captain Robert P. Parrott is now one of the sales engineers in the sales department of the new tungsten lamp, General Electric Company, Harrison, New Jersey.

Mr. Arthur G. Bierma is now connected with the drafting department in the Buffalo office of the Niagara, Lockport, and Ontario Power Company, Buffalo, N. Y.

Mr. I. W. Phillips, who has been with the North Mountain Power Company of Eureka, California, is now installing a hydroelectric plant at Klamath Falls, Oregon.

Mr. L. M. Wright, after a two months' vacation at home, has resumed work in the navy, as chief electrician in charge of the wireless telegraph station at New Orleans, La.

Mr. Montague Ferry, who has been employed by the Empire Construction Company of San Francisco, and been working there under Mr. S. G. McMeen, has returned to Chicago.

Professor Charles E. Hewitt has accepted a call as professor of electrical engineering of New Hampshire College, Durham, N. H. He will begin his new work about September 1.

Mr. Allen G. Jones has been transferred from the Chicago office of the General Electric Company, to their San Francisco office in connection with general supply work in that territory.

Mr. Charles P. Cooper has resigned from his position as instructor in electrical engineering at New Hampshire College, and is now with the New York and New Jersey Telephone Company.

Mr. J. C. Elberson has severed his connection with the Philadelphia Electric Company and taken charge of the plant of the Philadelphia & Western Railroad Company at Beechwood, Pa.

Mr. Byron T. Burt, the former manager of the Chattanooga Light and Power Company, has been made consulting resident electrical engineer of the Lock and Dam Company of that city.

Mr. W. E. Springsteel, for the last nine years chief engineer for Weil and Meyer, New York, has resigned to accept the position of superintendent for Clernand & Co., 64 Grand Street, New York.

Mr. Howard Shreve Fisher, for nearly 14 years with the Westinghouse Electric and Manufacturing Company, is now secretary of the Dictaphone Company of America, at 290 Broadway, New York.

Mr. Herbert W. Anderson, for over two years connected with the transformer engineering department of the General Electric Company at the Schenectady Works, has been transferred to the Pittsfield works.

Mr. O. C. Macy, formerly with the Cairo Electric & Traction Company, is now superintendent of the Alton Gas & Electric Company, and the Alton, Granite & St. Louis Traction Company, at Alton, Illinois.

Mr. W. A. Stock, for the past three years with the Western Electric Company, of Chicago, in their telephone engineering department, is now consulting engineer for Thomas Morris of San Francisco, California.

Mr. E. N. Sweitzer, of Canon City, Colorado, will spend two or three months hunting, fishing, and enjoying the scenery of Colorado, after which he expects to engage in hydroelectric work in the western states.

Mr. Edwin R. Pearson has recently been transferred from Schenectady to the Pittsfield works of the General Electric Company where he will continue to have charge of the designing of large shell-type transformers.

Mr. A. R. **Bush**, for many years district engineer for the General Electric Company in the New England district, has recently been made manager of the power and mining department, at Schenectady, New York.

Mr. W. H. **Sigourney**, for the past three years with the Connecticut Company, New Haven, is now attached to the local office of the General Electric Company, New Haven, Conn., in the capacity of commercial engineer.

Mr. **Robert A. Smith, Jr.**, is an engineering salesman with the Atwood-Rearick Company, No. 30 Church street, the company being eastern agents for the Kerr Steam Turbine Company and the Janesville Iron Works Company.

Mr. C. A. **Scott**, formerly connected with the California Gas and Electric Corporation in the capacity of construction foreman, is now chief electrician with the Great Western Power Company, at their Big Bend power plant.

Dartmouth College conferred on C. J. H. **Woodbury** at its Commencement, June 24, the degree of Doctor of Science, this being the second time that he has received the same degree, the first being from Union College, New York, in 1906.

Mr. H. W. **Tolle** formerly general superintendent and secretary of the Mattoon City Railway, and Mattoon Heat, Light and Power Co., of Mattoon, Illinois, is now general manager of the Cairo Electric and Traction Company of Cairo, Illinois.

Mr. **John C. Potter**, formerly instructor in the electrical engineering department of the University of Wisconsin, is now employed in the study branch of the traffic department of the American Telephone and Telegraph Company, New York.

Mr. W. W. **Lotspeich**, for two years electrical engineer and superintendent with the Light and Power Company of Marion, N. C., is now constructing engineer and general superintendent with the Piedmont Electric Company, engineers and contractors, Asheville, N. C.

Mr. H. B. **Zimmerman**, sales engineer of the Niagara, Lockport, and Ontario Power Company for the last two years, has assumed the management of the Depew and Lancaster Light Power & Conduit Company of Lancaster, N. Y., having also been elected its secretary and treasurer.

Mr. C. F. **Elwell**, is at present engaged in working on what are known as the McCarty Wireless Telephone patents, with a view to determining the feasibility of their development into a commercial system. This work is being done for the McCarty Wireless Telephone Company of Arizona.

Mr. **Robert B. Bonney**, for twelve years with the Colorado Telephone Company, in the technical branches of the business, has entered the electrical engineering field with Captain Lewis M. McBride, under the firm name of McBride & Bonney, with offices at 303 Jackson Block, Denver, Colorado.

Mr. **Alexander C. Lanier**, assistant professor of electrical engineering in the University of Cincinnati, and secretary of the Cincinnati Section, A.I.E.E., has resigned from the university, and will spend the coming year in graduate study in the Graduate School of Applied Science of Harvard University.

Mr. F. J. **Engelhorn** has been transferred from the Atlin Consolidated Mining Company at Atlin, B. C., to a like position with the Yukon Gold Company, at Dawson, Y. T., the transfer being in the nature of a promotion, as the operations on the Yukon are on a much more extensive scale than at the former place.

MR. WILLIAM L. NODELL, assistant instructor in mechanical drawing and descriptive geometry at the Polytechnic Institute, Brooklyn, during the past year, while taking courses for the degree of electrical engineer, has graduated from that institution. His address is 10-12 East 108th Street, New York City.

MR. JOHN J. FRANK, for ten years in the transformer department of the General Electric Company at Schenectady, has been made assistant engineer in the transformer department of their Pittsfield factory, being responsible for current and potential transformers, high-voltage, core-type, and testing transformers.

MR. WILLIAM MAYO VENABLE, formerly with the Florida East Coast Railway, under whose supervision the Long Key Viaduct was constructed, has become connected with the Ferro Concrete Construction Company of Cincinnati, and is now building Station "A" Southern Outfall Sewer, Louisville, Kentucky.

OTTO HOLSTEIN, until recently an inspector in the telegraph and telephone department of the Panama Railroad, with station at Culebra, Canal Zone, Panama, resigned his position to accept an appointment as general foreman, telegraph department, Cerro de Pasco Ry. Co., with station at Cerro de Pasco, Peru, S. A.

MR. WILLIAM HAND BROWNE, JR., formerly of Baltimore, Maryland, and a graduate of Johns Hopkins University, has been appointed professor of electrical engineering in the North Carolina Agricultural and Mechanical College, at Raleigh, N. C. Mr. Browne for some years has been technical editor of the *Electrical Review*.

MR. JOHN S. SCHUMAKER, until recently acting superintendent of power stations for the Boston Elevated Railway Company, has associated with Mr. Joseph V. Santry, and opened an office at No. 141 Milk street, Boston, Mass., as the New England representative of various manufacturers, representing a complete line of power plant equipment.

MR. JAMES H. HESSIN, general manager of the Bloomington, Pontiac and Joliet Electric Railway, and the Pontiac Light and Water Company, at Pontiac, Illinois, being compelled to give up business for a time on account of injuries received in an accident has resigned and gone to his old home in Huntington, Indiana, where he is now rapidly recovering.

MR. HAROLD W. CLAPP, for the last five years with the General Electric Company of Schenectady, part of the time as their New York City representative for the railway engineering and traction department, has resigned from that company and joined the electrical engineering staff of the Southern Pacific Company, with headquarters at the Flood Building, San Francisco.

MR. A. H. WINTER JOYNER having severed his connection with the Stone & Webster Engineering Corporation, has started business in Toronto, Ontario, under the name of Joyner-Greene. This firm will represent the Western Telephone Company, Weston Electrical Instrument Company, D. & W. Fuse Company, Helios Mfg. Co., A. & J. M Anderson, and other well-known United States manufacturers.

MR. A. J. MARSHALL, illuminating engineer, who has been associated respectively with the Welsbach Company and with the Holophane Company, is now connected with the Bureau of Illuminating Engineering of New York, in the capacity of chief consulting and designing illuminating engineer. The object of the Bureau is to handle any and all matters pertaining to the use of artificial light.

Mr. Lewis M. McBride, electrical engineer, and Mr. Robert B. Bonney, who for the past twelve years has been engaged in technical telephone and electrical work, have entered the electrical engineering field under the firm name of McBride & Bonney, with offices in the Jackson Block, Denver, Colorado, for the comlpete installation of lighting and power plants, and electrical and telephone equipment.

Mr. D. C. Findlay, formerly resident engineer of the Calgary Power & Transmission Company, Calgary, Alberta, has become associated with C. B. Pride, Columbia Building, Spokane, Washington, chief hydraulic engineer of the Chicago, Milwaukee and St. Paul Railway, who is preparing plans for the development of the St. Joseph River, Montana, to furnish power for the electrification of their new road in the West.

Mr. B. Parks Rucker, formerly designing and erecting engineer for the Westinghouse Electric and Manufacturing Company, is now engaged in consulting engineering work, with headquarters in the Trust Building, Charlotte, N. C., making a specialty of electric lighting and power equipments. He has planned and installed electric drive equipments in several cotton mills and other industrial plants, within the past year.

Mr. Henry L. Smith, formerly engineer of the supply department of the General Electric Company at the Pittsfield Works, has undertaken commercial engineering work with headquarters at Schenectady. Mr. Smith was secretary of the Pittsfield Section during the past season, and on the occasion of his departure the Section presented him with a handsome portfolio, and a leather case of toilet articles, in recognition of his active interest in the work of the Section.

Messrs. Charles D. Vail, former chief engineer for the Ely Townsite Company, Ely, Nevada; Chris J. Walbran, Jr., former manager of Dr. F. A. C. Perrine's Denver office; and Norman Read, engineer for the Hug Water Wheel Company, have associated themselves under the name of Vail, Walbran and Read to practice a general consulting engineering business, paying particular attention to hydroelectric developments, water-works and irrigation systems.

Mr. Benjamin Magnus is now general manager of the Electrolytic Refining and Smelting Company of Australia, Ltd., at Port Kembla, New South Wales, where he is building for them a large electrolytic copper, silver, and gold refinery, also a new smelter for copper, silver and gold ores. Mr. Magnus expects to instal a new process of his own for electrolytic silver refining. The plant will cost over one million dollars. Mr. Magnus is consulting engineer for the above company in all their enterprises.

Mr. W. J. Canada, formerly electrical engineer with the old Appleyard Interurban Railways of Ohio, and later for some years electrical inspector for the Ohio Inspection Bureau at Dayton, is now in charge of electrical matters for the Rocky Mountain Fire Underwriters. This field is a new and poorly inspected one, but electrical construction is gradually being brought into good shape with closer supervision, and better coöperation between the underwriters and the electrical interests.

Mr. Robert A. Hadfield, of Mayfair, London, England, has lately been created a Knight by King Edward, in celebration of the King's official birthday. The new Knight is a distinguished metallurgist, the inventor of manganese steel, and the head of a large firm of armor plate manufacturers in Leeds. His professional papers have won several medals, and he has been elected to many scientific societies. Sir Robert is a Member of the American Institute of Electrical Engineers.

MR. R. C. BEARDSLEY, of Warren, Ohio, is building three hydroelectric power plants for the Peerless Electric Company of that place. The output of 1,000 kw. will be sold in Warren and nearby towns. All the plants are built of reinforced concrete throughout. There are three 300-kw., 60-cycle, 2,200-volt, three-phase generators running at 300 rev. per min. The voltage is raised to 22,000 for transmission. The plants are provided with waste gates and sufficient turbines installed to provide for back water. With one exception, the dams are of the Beardsley Gravity type and have movable crests. The other dam is a reinforced concrete dam of the bow type and built with flash boards and an expansion joint at the base, so as to prevent any cantilever action.

Marseilles Electrical Congress

In connection with the International Exhibition of the Applications of Electricity now open at Marseilles, France, there will be held, September 14 to 21, 1908, an International Congress of the Applications of Electricity.

Members of the Institute who expect to attend the congress are requested to notify the secretary immediately, so that a list of Institute members who expect to be present may be forwarded to the officials of the congress.

The Institute has been invited to appoint delegates to the congress, and Mr. C. O. Mailloux has been appointed chairman of the Institute delegation.

Books Received

The following volumes have been received and placed in the Library of the Institute:

RADIO-ACTIVITY. By Fredk. Soddy, M.A. 214 pages, Illustrated. England: "The Electrician" Printing and Publishing Company, Ltd. 1904.

CONTENTS.—Chapter I.—Radiation Phenomena. II.—The Radio Active Elements—Uranium Thorium, Radium, Polonium and Actinium. III.—The Electrical Properties of Gases. IV.—Methods of Measuring Radio-Activity. V.—The α, β and γ-Rays. VI.—Uranium X and Thorium X. VII.—The Radio-Active Emanation of Thorium. VIII.—The Theory of Atomic Disintegration. IX.—The Radio-Active Properties of Radium. X.—The Material Properties of the Radium Emanation and Its Transmutation Into Helium. XI.—The Energy of Radio-Active Change. XII.—Anticipations.

A B C OF THE TELEPHONE. By James E. Homans, A.M. 346 pages. Illustrated. New York: Theo. Audel & Co. Price, $1.00.

CHAPTER I. The Telephone Apparatus and Its Operation. II. A brief Survey of the Theory of Sound, Necessary to an Understanding of the Telephone. III.—A Brief Survey of the Principles of Electricity. IV.—Electrical Quantities. V.—History of the Speaking Telephone. VI.—Later Modifications of the Magnet Telephone. VII.—The Carbon Microphone Transmitter. VIII.—The Circuits of a Telephone Apparatus. IX.—The Switch Hook and Its Function in the Telephone Apparatus. X.—The Switchboard and the Appliances of the Central Station. XI.—The Operator's Switch Keys and Telephone Set. XII.—Improved Switchboard Attachments. XIII.—Switchboard Lamp Signals and Circuits. XIV.—The Multiple Switchboard. XV.—Locally Interconnected or Multiple Transfer Switchboard. XVI.—Exchange Battery Systems. XVII.—Party Lines and Selective Signals. XVIII.—Private Telephone Lines and Intercommunicating Systems; Common Return Circuits. XIX.—Private Telephone Lines and Intercommunicating Circuits; Full Metallic Circuits. XX.—Large Private Systems and Automatic Exchanges. XXI.—Devices for Protecting Telephone Apparatus from Electrical Disturbances. XXII.—The General Conditions of Telephone Line Construction. XXIII.—Telephone Pole Lines. XXIV.—Wire Transpositions on a Pole Line. XXV.—Telephone Cables and Their Use in Underground and Pole Lines. XXVI.—Circuit Balancing Devices. XXVII.—The Microtelephone. XXVIII.—Wireless Telephony. XXIX.—Useful Definitions and Hints on Telephone Management.

Officers and Board of Directors, 1908-1909.

PRESIDENT.

LOUIS A. FERGUSON, Chicago, Ill.

JUNIOR PAST-PRESIDENTS.

SAMUEL SHELDON, Brooklyn, N. Y.
HENRY GORDON STOTT, New York, N. Y.

VICE-PRESIDENTS.

JAMES G. WHITE, New York, N. Y.
W. C. L. EGLIN, Philadelphia, Pa.

CUMMINGS C. CHESNEY, Pittsfield, Mass.
BANCROFT GHERARDI, New York, N. Y.
CALVERT TOWNLEY, New Haven, Conn.

MANAGERS.

JOHN J. CARTY, New York, N. Y.
A. M. SCHOEN, Atlanta, Ga.
PAUL M. LINCOLN, Pittsburg, Pa.
PAUL SPENCER, Philadelphia, Pa.

MORGAN BROOKS, Urbana, Ill.
HAROLD W. BUCK, New York, N. Y.
PERCY H. THOMAS, Montclair, N. J.
BENJAMIN G. LAMME, Pittsburg, Pa.

DAVID B. RUSHMORE, Schenectady, N. Y.
W. G. CARLTON, New York N. Y.
CHARLES W. STONE, Schenectady, N. Y.
H. E. CLIFFORD, Boston, Mass.

TREASURER.

GEORGE A. HAMILTON, New York, N. Y.

SECRETARY.

RALPH W. POPE, New York, N. Y.

PAST-PRESIDENTS.

T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
ALEX. GRAHAM BELL, 1891-2.
FRANK J. SPRAGUE, 1892-3.
EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS B. CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1901.
CHARLES P. STEINMETZ, 1901-2
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, JR., 1904-5.
SCHUYLER S. WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.

ASSISTANT SECRETARY.

FREDERICK L. HUTCHINSON,
33 West 39th Street, New York, N.Y.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York, N. Y.

Standing Committees.

EXECUTIVE COMMITTEE.

H. G. STOTT, Chairman.
600 W. 59th Street, New York.
C. C. CHESNEY, Pittsfield, Mass.
C. L. EDGAR, Boston, Mass.
GEO. A. HAMILTON, New York.
RALPH W. POPE, New York.
CALVERT TOWNLEY, New Haven, Conn.
JOHN J. CARTY, New York.

FINANCE COMMITTEE.

CALVERT TOWNLEY, Chairman.
Consolidated Railway Co., New Haven, Ct
H. W. BUCK, New York.
BANCROFT GHERARDI, New York.

LIBRARY COMMITTEE.

EDW. CALDWELL, Chairman.
239 West 39th Street, New York.
MORGAN BROOKS, Urbana, Ill.
MAX LOEWENTHAL, New York.
F. A. SCHEFFLER, New York.
PHILIP TORCHIO, New York.

MEETINGS AND PAPERS COMMITTEE.

A. H. ARMSTRONG, Chairman.
Schenectady, N. Y.
PAUL M. LINCOLN, Pittsburg, Pa.
RALPH D. MERSHON, New York.
H. H. NORRIS, Ithaca, N. Y.

STANDARDS COMMITTEE.

SAMUEL SHELDON, Chairman.
Polytechnic Institute, Brooklyn, N. Y.
B. A. BEHREND, Cincinnati, O.
A. E. KENNELLY, Cambridge, Mass.
D. C. JACKSON, Boston, Mass.
CHAS. F. SCOTT, Pittsburg, Pa.
C. H. SHARP, New York.
C. P. STEINMETZ, Schenectady, N. Y.
L. B. STILLWELL, New York.
S. W. STRATTON, Washington, D. C.

EDITING COMMITTEE.

GEORGE F. SEVER, Chairman.
Columbia, University, New York.
W. H. BROWNE, Jr., New York.
PERCY H. THOMAS, New York.

BOARD OF EXAMINERS.

HAROLD W. BUCK, Chairman.
49 Wall Street, New York.
H. H. BARNES, Jr., New York.
MAURICE COSTER, New York.
W. C. L. EGLIN, Philadelphia, Pa.
GEORGE F. SEVER, New York.

SECTIONS COMMITTEE.

PAUL SPENCER, Chairman.
Broad and Arch Streets, Philadelphia, Pa.
WILLIAM ESTY, Bethlehem, Pa.
H. H. NORRIS, Ithaca, N. Y.
D. B. RUSHMORE, Schenectady, N. Y.
P. B. WOODWORTH, Chicago, Ill.

CODE COMMITTEE.

F. A. C. PERRINE, Chairman.
60 Wall Street, New York.
J. C. FORSYTH, New York.
A. M. SCHOEN, Atlanta, Ga.
GEORGE F. SEVER, New York.
H. A. SINCLAIR, New York.
H. S. WARREN, New York.
ARTHUR WILLIAMS, New York.

LAW COMMITTEE.

C. O. MAILLOUX, Chairman.
76 William Street, New York.
A. H. ARMSTRONG, Schenectady, N. Y.
H. A. LARDNER, New York.
E. A. SPERRY, Brooklyn, N. Y.
C. A. TERRY, New York.

Special Committees.

BUILDING FUND COMMITTEE.

T. C. MARTIN, Chairman.
239 W. 39th Street, New York.
J. C. BARCLAY, New York.
J. J. CARTY, New York.
C. L. EDGAR, Boston, Mass.
F. W. JONES, New York.
J. W. LIEB, Jr., New York.
F. J. SPRAGUE, New York.
J. G. WHITE, New York

COMMITTEE ON INCREASE OF MEMBERSHIP.

D. B. RUSHMORE, Chairman.
Schenectady, N. Y.
A. W. BERRESFORD, Milwaukee.
S. S. DICKENSON, New York.
GANO DUNN, Ampere, N. J.
BANCROFT GHERARDI, New York.
F. L. HUTCHINSON, New York.
S. M. KINTNER, Pittsburg.
A. P. PECK, New York.
W. L. WATERS, Milwaukee.

HIGH-TENSION TRANSMISSION COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
RALPH D. MERSHON, Chairman.
60 Wall Street, New York.
F. G. BAUM, San Francisco.
C. C. CHESNEY, Pittsfield, Mass.
B. G. LAMME, Pittsburg.
PAUL M. LINCOLN, Pittsburg.
W. S. MOODY, Schenectady.
W. N. RYERSON, Niagara Falls, N. Y.

JOHN FRITZ MEDAL REPRESENTATIVES.

HENRY G. STOTT.
SAMUEL SHELDON.
SCHUYLER S. WHEELER.
JOHN W. LIEB, Jr.

RAILWAY COMMITTEE

(Sub-com. of Meetings and Papers Committee.)
A. H. ARMSTRONG, Chairman.
Schenectady, N. Y.
WM. McCLELLAN, New York.
H. ST. C. PUTNAM, New York.
C. W. RICKER, Cleveland, O.
N. W. STORER, Pittsburg, Pa.

CODE OF ETHICS COMMITTEE.

SCHUYLER S. WHEELER, Chairman.
Ampere, N. J.
BION J. ARNOLD, Chicago.
H. W. BUCK, New York.
J. J. CARTY, New York.
L. A. FERGUSON, Chicago, Ill.
B. G. LAMME, Pittsburg.
J. W. LIEB Jr., New York.
C. F. SCOTT, Pittsburg.
SAMUEL SHELDON, Brooklyn.
C. P. STEINMETZ, Schenectady, N. Y.
L. B. STILLWELL, New York.

EDUCATIONAL COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
HENRY H. NORRIS, Chairman,
Cornell University, Ithaca, N. Y.
GANO DUNN, Ampere, N. J.
DUGALD C JACKSON, Boston, Mass.
C. O. MAILLOUX, New York.
CHARLES F. SCOTT, Pittsburg, Pa.

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

United States National Committee.

ELIHU THOMSON, President, Lynn, Mass.
CHARLES F. SCOTT, 1st Vice-president.
SAMUEL SHELDON, 2d Vice-president.
BION J. ARNOLD,
B A. BEHREND,
ARTHUR W. BERRESFORD,
JOHN J. CARTY,
W. C. L. EGLIN,
CARL HERING,
JOHN W HOWELL,
DUGALD C. JACKSON,
FRANCIS W. JONES,
ARTHUR E. KENNELLY,
BENJAMIN G. LAMME,
W. A. LAYMAN,
JOHN W. LIEB, Jr.,
CLAYTON H. SHARP,
CHARLES P. STEINMETZ,
LEWIS B. STILLWELL,
HENRY G. STOTT,
SAMUEL W. STRATTON

COMMITTEE ON FOREST PRESERVATION.

C. H. PORTER, Chairman.
Mass. Inst. Technology, Boston.
R. G. BLACK, Toronto, Ont.
P. G. GOSSLER, New York.
A. M. SCHOEN, Atlanta, Ga.
J. A. THALER, Bozeman, Mont.
C. A. WADDELL, Biltmore, N. C.

COMMITTEE ON BIBLIOGRAPHY.

WM. D. WEAVER, 239 W. 39th St., New York

Sections and Branches—Directory.

Name and when Organized.	Chairman.	Secretary.	Regular Meeting.
SECTIONS.			
Atlanta............Jan. 19, '04	J. H. Finney.	G. J. Yundt.	1st Tuesday.
Baltimore.........Dec. 16, '04	J. B. Whitehead.	C. G. Edwards.	2d Friday.
Boston............Feb. 13, '03	A. E. Kennelly.	A. L Pearson.	3d Wednesday
Chicago.................1893	H. R. King.	J. G. Wray.	1st Tuesday after N. Y. meeting.
Cincinnati.........Dec. 17, '02	A. G. Wessling.	A. C. Lanier.	3d Wednesday.
Cleveland........Sept. 27, '07	Henry B. Dates.	F. M. Hibben.	3d Monday.
Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Bachman.	1st Wednesday.
Fort Wayne.......June 12, '08	E. A. Wagner.	M. J. Kehoe.	
Ithaca............Oct. 15, '02	E. L. Nichols.	H. H. Norris.	1st Friday after N. Y. meeting.
Los Angeles........May 19, '08			
Mexico...........Dec. 13, '07	R. F. Hayward.	F. D. Nims.	
Minnesota..........Apr. 7, '02	E. H. Scofield.	A. L. Abbott.	2d Monday after N. Y meeting.
Norfolk...........Mar. 13, '08	R. R. Grant.	F. W. Walter.	
Philadelphia.......Feb. 18, '03	Paul Spencer.	H. F. Sanville.	2d Monday.
Pittsburg..........Oct. 13, '02	C. E. Skinner.	R. A. L. Snyder.	1st Wednesday.
Pittsfield..........Mar. 25, '04	J. Insull.	H. L. Smith.	3d Friday.
San Francisco......Dec. 23, '04	A. M. Hunt.	G. R. Murphy.	4th Friday.
Schenectady.......Jan. 26, '03	D. B. Rushmore.	J. M. Knox.	Every Friday.
Seattle............Jan. 19, '04	J. H. Harisberger.	George H. Moore.	3d Saturday.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	H. I. Finch.	2d Wednesday
Toledo............ June 3, '07	C. R. McKay.	Geo. E. Kirk.	1st Friday.
Toronto..........Sept. 30, '03	W. A. Bucke.	W. G. Chace.	2d Friday.
Urbana...........Nov. 25, '02	J. M. Bryant.	E. B. Paine.	1st Wednesday after N.Y. meeting.
Washington, D. C...Apr. 9, '03.	Philander Betts.	L. D. Bliss.	2d Wednesday.

Sections and Branches—Directory.

Name and when Organized.	Chairman.	Secretary.	Regular Meeting.
BRANCHES.			
Univ. of Arkansas..Mar. 25, '04	M. F. Thompson.	C. R. Rhodes.	Alternate Mondays.
Armour Institute...Feb. 26, '04	T. C. Oehne, Jr.	J. E. Snow.	1st & 3d Thursdays.
Univ. of Cincinnati..Apr. 10, '08	C. R. Wylie.	C. C. Buchanan.	
Univ. of Colorado..Dec. 16, '04	H. H. Watters.	L. D. Jones.	1st and 3d Wednesdays.
Iowa State College..Apr. 15, '03	F. A. Fish.	Adolph Shane.	1st and 3d Wednesdays.
Kansas State Agr. Col., Jan. 10, '08	W. L. Enfield.	Kirk H. Logan.	
Univ. of Kansas....Mar. 18, '08	Martin E. Rice.	H. P. Broderson.	Alternate Thursdays
Lehigh University..Oct. 15, '02	H. O. Stephens.	J. A. Clarke, Jr.	2d Tuesday.
Lewis Institute.... Nov. 8, '07	W. H. Hayes.	P. B. Woodworth.	2d Wednesday.
Univ. of Maine ....Dec. 26, '06		Gustav Wittig.	
Univ. of Michigan..Mar. 25, '04	C. M. Davis.	H. F. Baxter.	1st and 3d Wednesdays.
Univ. of Missouri..Jan. 10, '03	H. B. Shaw.	H. D. Carpenter.	1st and 3d Fridays.
Univ. of Montana..May 21, '07	Robert Sibley.	S. R. Inch.	1st Thursday.
Montana Agr. Col..May 21, '07	B. S. Hind.	J. A. Thaler.	1st Friday.
Univ. of Nebraska..Apr. 10, '08	George H. Morse.	L. E. Hurtz.	
Ohio State Univ....Dec. 20, '02	F. W. Funk.	F. C. Caldwell.	Alternate Wednesdays.
Oregon State Agr. Col., Mar. 24, '08	E. V. Hawley.	E. C. Wiggin.	
Penn. State College. Dec. 20, '02	D. R. Simpson.	C. D. Preston.	Every Wednesday
Purdue University..Jan. 26, '03	J. W. Esterline.	H. T. Plumb.	Every Tuesday.
Stanford Univ......Dec. 13, '07	W. C. North.	A. J. Gowan.	
Syracuse Univ.....Feb. 24, '05	W. P. Graham.	R. A. Porter.	1st and 3d Thursdays.
Univ. of Texas.....Feb. 14, '08	A. C. Scott.	B. F. Kenyon.	2d and 4th Fridays.
State Col. of Wash..Dec. 13, '07	H. V. Carpenter.	M. K. Akers.	3d Tuesday.
Washington Univ..Feb. 26, '04	C. M. Duncan.	W. E. Beatty.	2d and 4th Wednesdays.
Univ. of Wisconsin.Oct. 15, '02	O. H. Ensign.	J. W. Shuster.	Every Thursday. [4th Thursday (Public Meeting.)]
Worcester Poly. Inst. Mar. 25, '04	L. W. Hitchcock	W. D. Stearns.	Alternate Fridays.

Section and Branch Secretaries.

AMES, IOWA.—ADOLPH SHANE,
Iowa State College.

ANN ARBOR, MICH.—H. F. BAXTER,
556 S. State St.

ATLANTA, GA.—G. J. YUNDT,
Southern Bell Tel. & Tel. Co.

AUSTIN, TEXAS.—B. F. KENYON,
University of Texas

BALTIMORE, MD.—CHAS. G. EDWARDS,
Electrical Commission, City Hall

BETHLEHEM, PA.—J. A. CLARKE, Jr.,
Lehigh University.

BOSTON, MASS.—A. L. PEARSON,
93 Federal St.

BOULDER, COLO.—H. S. BUCHANAN,
University of Colorado.

BOZEMAN, MONT.—J. A. THALER,
Montana Agricultural College.

CHICAGO, ILL.—J. E. SNOW,
Armour Inst. of Technology.

CHICAGO, ILL.—P. B. WOODWORTH,
Lewis Institute.

CHICAGO, ILL.—J. G. WRAY,
Chicago Telephone Co.

CINCINNATI, O.—A. C. LANIER,
University of Cincinnati.

CINCINNATI, O.—C. C BUCHANAN,
University of Cincinnati.

CLEVELAND, O.—F. M. HIBBEN,
10207 Wilbur Avenue.

COLUMBIA, MO.—H. D. CARPENTER,
University of Missouri.

COLUMBUS, O.—F. C. CALDWELL,
Ohio State University.

COLUMBUS, O.—H. L. BACHMAN,
533 South 3d St

CORVALLIS, ORE.—E. C. WRIGHT,
Oregon Agr. College.

FAYETTEVILLE, ARK.—C. R. RHODES,
University of Arkansas.

ITHACA, N. Y.—H. H. NORRIS,
Franklin Hall, Cornell University.

LAFAYETTE, IND.—H. T. PLUMB,
Electrical Eng. Dept., Purdue University

LAWRENCE, KAN.—H. P. BRODERSON,
University of Kansas.

LINCOLN, NEB.—L. E. HURTZ,
Lincoln Tel. Co.

MADISON, WIS.—J. W. SHUSTER,
University of Wisconsin.

MANHATTAN, KAN.—KIRK H. LOGAN,
Kansas State Agr. College.

CITY OF MEXICO.—F. D. NIMS,
Mexican Light & Power Co.

MISSOULA, MONT.—S. R. INCH,
Univ. of Montana.

NORFOLK, VA.—F. W. WALTER,
National Bank of Commerce.

ORONO, MAINE,—GUSTAV WITTIG,
University of Maine.

PENN. STATE COLLEGE,PA.—C. D. PRESTON,
Penn. State College.

PHILADELPHIA, PA.—H. F. SANVILLE,
1122 North American Building.

PITTSBURG, PA.—R. A. L. SNYDER,
1332 Fulton Building.

PITTSFIELD, MASS.—H. L. SMITH,
Stanley-G. I. Elec. Mfg. Co.

PULLMAN, WASH.—M. K. AKERS,
State College of Washington.

ST. LOUIS, MO.—C. M. DUNCAN,
Washington University.

ST. LOUIS, MO.—H. I. FINCH,
5217 Morgan Street.

ST. PAUL, MINN.—A. L. ABBOTT,
165 E. 4th St.

SAN FRANCISCO, CAL.—G. R. MURPHY,
11 Hawthorne St., San Francisco.

SCHENECTADY, N. Y—J. MASON KNOX,
General Electric Co.

SEATTLE, WASH.—GEORGE H. MOORE,
1726 Harvard Ave.

STANFORD UNIVERSITY.—A. J. GOWAN,
Leland Stanford, Jr., University.

SYRACUSE, N. Y.—R. A. PORTER,
Syracuse University.

TOLEDO, OHIO.—GEO. E. KIRK,
The Nicholas.

TORONTO, ONT.—W. G. CHACE,
551 Confederation Life Building.

URBANA, ILL.—ELLERY B. PAINE,
University of Illinois.

WASHINGTON, D. C.—PHILANDER BETTS,
Metropolitan Bank Bldg.

WORCESTER MASS.—S. W. FARNSWORTH,
Worcester Poly. Inst.

Local Honorary Secretaries.

JAMES S. FITZMAURICE,
210 George St., Sydney, N. S. W.

H. F. PARSHALL,
Salisbury House, London Wall E. C., London.

ROBERT B. OWENS,
McGill University, Montreal, P. Q.

WILLIAM B. HALE,
1a Independencia No. 6, City of Mexico

CLARE F. BEAMES,
for Porto Rico and West Indies,
San Juan, P. R.

W. G. T. GOODMAN,
Adelaide, South Australia.

ROBERT J. SCOTT,
Christ Church, New Zealand.

PROCEEDINGS
OF THE
American Institute
OF
Electrical Engineers.

Published monthly at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE
GEORGE F. SEVER, Chairman
A. H. ARMSTRONG   SAMUEL SHELDON

GEORGE A. WARDLAW, Editor

Subscription. United States, Mexico and Cuba, $5.00 per year.
All other countries $6.00 per year.
Single copy 50 cents.
Subscriptions must begin with January issue.

Advertisements accepted from reputable concerns at the following net rates:

Space	Less than half year per issue	Half year per issue	One year per issue
1 page	$36.00	$32.00	$30.00
½ page	22.00	18.00	16.00

Additional charges for Preferred Positions.
Professional Cards, special rate of $25.00 per year.

Vol. XXVII **September, 1908** No. 9

Transactions for 1907

VOLUME XXVI of the TRANSACTIONS for 1907, aggregating 1836 pages, has been received from the bindery and will shortly be distributed among the Members and Associates that have paid their dues to May 1, 1908. Members and Associates in arrears for the time covered by these TRANSACTIONS are, in accordance with the Institute By-Laws, not entitled to receive this volume. Volume XXVI consists of two parts, designated respectively Part I and Part II. Part I, consisting of 936 pages, contains the papers and discussions from January 1 to May 31, 1907, and the report of the Board of Directors for the fiscal year ending April 30, 1907. Part II, consisting of 900 pages, contains the papers and discussions from June 1 to December 31, 1907, and the Standardization Rules approved by the Board of Directors on June 21, 1907. The TRANSACTIONS for 1906 were contained in one volume consisting of 952 pages; the 1836 pages of Volume XXVI indicate, therefore, an increase of almost 90% in the amount of TRANSACTIONS over those of the preceding year.

Institute Committees

AT the meeting of the Board of Directors held August 14, 1908, President Ferguson announced his appointment of committees for the current administrative year expiring July 31, 1909. The selection of members to serve on these committees is a matter of vital importance to the welfare of the Institute, as the value of its work depends upon their activity and judgment. The president expects to avail himself of the constitutional privilege of enlarging some of the more active committees by the appointment of auxiliary members as conditions may demand. A list of the committees as they now stand appears in this issue. Those which have not yet been appointed will be printed later.

Literary Thieves

THERE seems to be no practical safeguard against the loss of books and periodicals from libraries which are open to the public, or even where the visitors are carefully restricted as, for instance, in a club library. In one prominent club in New York a list is posted of twelve different magazines permanently "borrowed" during one month. The loss of periodicals or modern books is not usually regarded as serious, but even these cannot always be replaced. A copy of London *Engineering*, dated November 27, 1907, has been stolen from each of the files of the American Institute of Electrical Engineers, and of the American Society of Mechanical Engineers, both located in the Engineers' Library. This particular issue is out of print, and efforts to replace the stolen copies have been futile. Copies of each of two recently published engineers' handbooks have been stolen from the same library. Public libraries throughout the country in many cases lose over 1000 volumes annually. A theory exists that it is better to lose a small percentage of books than place objectionable restrictions upon their accessibility. It is an exceedingly difficult matter to guard against this evil practice, as proof of guilt is not readily obtainable.

Historic Collection

An interesting relic of the earlier days of the telegraph has been received from Mr. Oscar T. D. Brandt, of Tacoma, Washington. It is a " hook " insulator, which was recently removed from an old cedar pole in the woods during the clearing of a right of way for a telephone line to Seattle. Early in the sixties, when the uprisings of the Indians in the extreme West were frequent and serious, the government found it necessary to dispatch troops to Seattle. To facilitate their movements a military road was constructed between Seattle and a town called Slaughter, so named from a great massacre which occurred there, now known as Auburn. Along this road a telegraph line was built, and insulators of this type were used. Scarcely a vestige of the old telegraph line remains to-day, except a few of the split cedar poles still standing. Notwithstanding its age and years of exposure to the elements, the insulator is in a remarkably good state of preservation, the wooden portion being perfectly sound, and the iron hook and spikes in excellent condition, though slightly corroded. It consists of a simple block of wood in which an iron hook very much like a double-pointed clothes-hook has been sunk. The hook retains portions of the insulating material, which appears to be hard rubber. Three iron spikes were used to fasten the insulator to the pole.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before September 11, 1908.

7795 Taber, E. R., Jr., Mountain Creek, Ala.
7796 Bates, C. W., New Haven, Conn.
7797 Hoar, F. E., Oakland, Cal.
7798 Murray, H. H., Alberto Torres Est. de Rio, South America.
7799 Tellington, Jesse James, Berlin, N. H.
7800 Wilson, H. C., Kingston, Jamaica, B. W. I.
7801 Gleason, F. J., Walpole, Mass.
7802 Evers, C. H., Birmingham, Ala.
7803 Glennie, F. I., Mexico D. F., Mex.
7804 Van Horne, J. S., New York City.
7805 Zeigler, Guy, East Orange, N. J.
7806 Payne, Louis, Covington, Va.
7807 Newby, J. H., Melbourne, Victoria, Australia.
7808 Neiswanger, E. B., Colorado Springs, Colo.
7809 Clarke, A., Folsom, W. Va.
7810 Clements, O. S., Colon, Panama.
7811 Stone, Ernest Frank, Norfolk, Va.

Applications for Transfer

Recommended for transfer by the Board of Examiners, July 30, 1908. Any objection to these transfers should be filed at once with the secretary.

EDWARD BELDEN MERRILL, Chief Assistant Engineer, Winnipeg Power Department, Winnipeg, Canada.

WILLIAM NOBLE DICKINSON, JR., Manager Foreign Department, Otis Elevator Company, 17 Battery Place, New York City.

JOHN KNOWLTON ROBINSON, Electrical Engineer and Agent, Westinghouse Electric and Mfg. Company, 116 Broad St., New York, and Iquique, Chili, South America.

Professor Anthony at Cornell*

BY E. L. NICHOLS

Professor William A. Anthony was graduated at the Sheffield Scientific School (Yale) with the class of 1860. He taught school in New England for a time, then served for several years as a professor at Antioch College in Ohio and later at the Iowa State College. In 1872 he was called to the Chair of Physics at Cornell.

At that time the Department of Physics shared with Chemistry a large wooden building which has long since disappeared from the Campus; but McGraw Hall was nearing completion and a lecture room in the south wing of that building had been assigned to Physics. During the Christmas vacation what little equipment for the illustration of this subject then existed was moved into the new quarters. There was no provision for laboratory work and for some time the space under the lecture-room seats and the lecture room itself had to be used as a laboratory. This was found to be inadequate, even for the few students in the subject, and two or three rooms in Morrill Hall were also temporarily used for physical laboratory work. In these cramped quarters the department lived for eleven years.

When William A. Anthony one day in the winter of 1872–73 stood for the first time before a Physics class at Cornell, something very like a miracle took place. To the undergraduate, Physics had thus far been a mere dead name in the list of studies: the moment he opened his mouth it became a live thing. To many of his pupils of those early days the recollection of Professor Anthony's lectures and demonstrations is among the most vivid and vital of all their college experience.

It is hard to realize the changes that have occurred since Professor Anthony began his work at Cornell. Imagine an industrial civilization without dynamos or motors, storage batteries, electric lights, trolley cars, telephones, or the wireless telegraph; think of physics without the diffraction grating of Rowland, the interferometer of Michelson, or the bolometer of Langley. The liquefaction of the permanent gases was still unattained. X-rays and radioactivity were yet not even a subject for dreams.

Many applications of Physics and especially of electricity to industrial life were, however, in process of development during these years, and Professor Anthony, impelled by the passion to try things out for one's self in a practical way which characterizes the experimental physicist, rapidly gathered together a unique equipment. In these labors he was fortunate in the skilful and ingenious coöperation of one of his pupils, G. S. Moler, now professor in the Department of Physics, whose name is inseparably associated with all of this pioneer work.

In 1875, Gramme brought out in Paris his form of dynamo machine, and no sooner had the description of it reached this country than Anthony and Moler undertook to build one. They made their own design, based upon Gramme's principle but adapted to the special uses of the laboratory, and long before the first imported dynamos reached America this machine was successfully completed and in operation. With it, before the close of the year, arc lamps were installed on the campus and were put into regular service; and thus it came about that inhabitants of remote farms among the hills of Central New York saw the arc light shine out night after years before the introduction of this means of illumination in Paris, London, Berlin, New York or any of the great cities of the world. The wiring of this lighting system is of considerable historical importance. Underground cables were constructed of gas piping through which copper wires were drawn. These wires were so thoroughly insulated by means of a composition of tallow pumped into the pipes that when tested after having been buried more than twenty years they were found to be still in excellent condition.

---

* Reprinted from *The Sibley Journal of Engineering*, April, 1908.

This Gramme machine, which served to light the campus by night, was used in a variety of other work during the day time. Lanterns for lecture room use were at that period supplied with the limelight for which oxygen and hydrogen gas had to be prepared by chemical means. Professors Anthony and Moler substituted an apparatus for the electrolytic generation of these gases. So far as I know it was the first of its kind. This generator for many years supplied oxygen and hydrogen for lanterns and for use in the various departments of the University.

The Gramme machine constructed in 1875, and which made these and many other interesting things possible, was exhibited at the Centennial Exhibition in 1876 where it attracted much attention as the first example of American dynamo construction, at the Electrical Exhibition of the Franklin Institute in 1884, at the Pan-American Exhibition and at the World's Fair in St. Louis in 1904. At the Centennial it was a novelty, at St. Louis, an historical exhibit, the importance of which was recognized by the awarding of silver medals to the constructors. Now after a third of a century, during which time it has been in constant use, this interesting machine is still in daily service as a motor and furnishes power to the student's shop in Rockefeller Hall. Many more modern machines have since come and gone to the scrap heap, but this one still survives and during its long life has never needed repairs which could not be readily done in the workshop of the department.

In the early 80's Professor Anthony, who was always warmly interested in the practical applications of Physics, began to urge the establishment of a special course for electrical students. The result was the announcement of the course in Electrical Engineering in Sibley College at a time when no such courses were given either in Europe or America. Cornell's example was, however, speedily followed, and, within the next few years, similar courses were announced by nearly all the technical schools of the country. In the meantime plans were being drawn for a new physical laboratory and in 1885 Franklin Hall was built. It was not, however thought necessary to provide an entire building for the work in Physics and Electrical Engineering. Lecture room accommodations for 150 and a laboratory for 80 students were thought to be ample even for the distant future. The new building was accordingly about equally divided between the departments of Chemistry and of Physics, and the latter department was expected, in the space allotted to it, to afford facilities for the electrical work of the engineers.

As an important feature of the new work in electricity, Professor Anthony planned during the years 1884–86 an elaborate and complete equipment for absolute measurements in electricity and magnetism. For this purpose an isolated building, in the construction of which iron was scrupulously avoided, was erected to the west of the then existing buildings of Sibley College. In this structure, which was popularly known as the " copper house," the instruments were mounted; among others a tangent galvanometer* for the measurement of heavy currents which far exceeded in size and accuracy of construction anything attempted before or since. This plant, although admirably designed for its purpose, was unfortunately very short-lived. The rapid growth of Sibley College compelled the construction of buildings containing large amounts of iron and of moving machinery in the immediate neighborhood of the copper house, whereby the constancy of the magnetic field upon which it entirely depended was greatly interfered with. The extension of the electric railway across the campus completed the demoralization of the earth's magnetic forces and compelled the abandonment altogether of an equipment upon which several thousand dollars and several years of time had been expended.

---

*"The Great Tangent Galvanometer of the Cornell University," by Wm. A. Anothony. TRANSACTIONS A. I. E. E. Vol. III, p. 67. [Out of print.]

During the first few years after the announcement of courses in instruction for Electrical Engineers the number of students was comparatively small and Professor Anthony was able to give personally the entire instruction offered in electrical subjects. Quality, in the student body, seems, however, to have compensated for lack of quantity for we find among the handful of students of that period the names of Ernest Merritt, Harris J. Ryan, J. G. White, and Benjamin W. Snow.

In 1887, too soon to reap the fruits of his years of labor, Professor Anthony resigned his professorship at Cornell to enter upon the practice of the profession of electrical engineering. Love of teaching, however, was too strong for him and after five years of industrial work he returned to the calling to which he had devoted the best years of his early life. As professor of Physics and Applied Electricity in the Schools of the Cooper Union in New York he has again demonstrated his remarkable powers as a teacher and organizer and has built up a great department for the practical instruction of artisans in the fundamental science upon which all engineering is based.

New York Railroad Club

The next meeting of the New York Railroad Club will be held on the third Friday of September, 1908. Mr. R. Emerson, assistant engineer of methods, The Atchison, Topeka and Santa Fe Railway system of Topeka, Kansas, will read a paper entitled, "Handling Locomotive Supplies: Value of Proper Handling of Supplies, Supply Costs and Accounting, Design of Items of Engine Equipments, Methods of Handling Supplies and Equipments, Results."

Closing Session of the Twenty-fifth Annual Convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29-July 2, 1908

President Stott: I think at no convention I can recall within the last five or six years have we had such a pleasant time as we have had here.

There is one other matter I wish to bring to your attention at this time, as the period of the present administration approaches a close. We established the custom last year that the chairman of the Meetings and Papers Committee should resign immediately after the convention in order to enable his successor to be appointed and take hold of the work in preparation for the ensuing year. In accordance with this custom, Mr. Thomas has resigned to-day and at President Ferguson's request I have great pleasure in appointing Mr. A. H. Armstrong chairman of the Meetings and Papers Committee for the ensuing year. I feel sure he will have your hearty coöperation in his work for the coming year.

A. F. Ganz: I wish to offer a vote of thanks to Mr. Thomas, as the retiring chairman of the Meetings and Papers Committee, for the excellent work that he has done for us. The membership is indebted to him for having provided a very fine set of papers at the convention, and especially in having had nearly all of these papers published in the Proceedings several weeks before the convention.

The motion was seconded by Dr. Steinmetz and unanimously carried.]

President Stott: I wish to say one or two words in regard to the work of the committees. Without any invidious comparison in regard to the work of the various Institute committees, unquestionably the work of the Meetings and Papers Committee is the most important one of all. No one realizes, unless he has been through it, just how much work it means. The chairman of the Meetings and Papers Committee not only arranges for the papers themselves, but also arranges for the discussions. It has been found, as the result of several years' experience, that unless there are prepared discussions by two or three members of the Institute, that the discussion of the papers may not be satisfactory; in other words, it is advisable to start the discussion in the right direction, and then open the subject for general discussion. This practice has been followed most successfully during Mr. Thomas's term. The success of the meetings during the last year is due almost entirely to his efforts.

I want to say, however, a few words about the other committees. The Sections Committee under Mr. Spencer has also contributed very largely to the success of the Institute during the past year. The work of this committee has become so onerous that we hope we shall be able to relieve the chairman somewhat in the coming year, in accordance with President-elect Ferguson's wishes, by the appointment of a special assistant to the secretary, whose duty will be to look after the Sections under the guidance of the chairman of the Sections Committee. A committee of which you hear very little, and whose work is of a thankless order, is the Board of Examiners. They are doing a great work for the Institute. They receive all applications for membership and pass on them, and also receive all applications for transfer from the grade of Associate to that of Member. Their work has been very effective, and we are also deeply indebted to them, as the standing of the members of this Institute is largely under their control.

The next important committee is probably the Finance Committee, whose work is also of such a character that our members do not see or hear much about it. They have to approve all the bills, pay-rolls, etc., and everything of that character in connection with the Institute work. Generally this committee directs the financial policy of the Institute. This entails very frequent meetings in New York, to go over these accounts. A great deal of most careful and painstaking work is done by the committee. The Editing Committee is also highly commendable for the careful and painstaking work which they do.

I have had some experience in the management of the affairs of some other societies and associations, and I believe that the great secret of the success of the American Institute of Electrical Engineers lies in the enthusiastic work of its committees. No paid official will do the work with the enthusiasm that is now shown by all of our voluntary committees. In my opinion that is the secret of the success of the American Institute of Electrical Engineers, and I hope that policy will always be continued.

President Stott: We have with us a gentleman who wishes to say a few words on the subject of forest preservation.

John H. Finney: I won't take very much of your time. We have been talking so much about education at this convention that it is surprising we have not touched on one very large job of education that ought to be tackled. A distinguished citizen of the United States, who has a high position, the Speaker of the House of Representatives, said not long ago that "if you get a grain of wheat out of a bushel of chaff from the scientists, and alleged scientists, who are talking of the conservation idea, it would be a good thing for the country." We might attempt some political education.

As President Stott said yesterday, this conservation movement ought to have as its leaders the engineers. It is a fact that the resolutions presented by the engineers at the Washington Conference were practically adopted as a whole. However much we may be in sympathy with the work of the Conference, our sympathies are not effective until we exert them. In my opinion every Section chairman and every Section secretary ought to go back home and talk the conservation idea. The President of the United States has appointed a great Conservation Commission to investigate and report on soils, waters, ores, and forests, and they are to coöperate with State Commissions which are being appointed by the Governors of the several states; for after all it is the work which the states must do that is going to count most largely in this conservation idea. I think the members of this Institute can do a great deal in bringing about the prevention of waste of our natural resources. It is work that must be done locally, and I want to urge that the Institute members in the various states get behind this movement—or rather, not to get behind it but to lead it. It is work that is worthy of the very best efforts of everybody connected with the Institute and will reflect credit on them in large measure.

ELIHU THOMSON: I have a resolution which I would like to offer. It is as follows:

Resolved, That it is the sense of the members of the Institute that the joint action taken by the presidents of the national engineering societies at the recent Conference held in Washington in response to a call by the President of the United States, concerning the conservation of our natural resources, is worthy of the highest commendation and an important indication of the possible influence of these organizations upon the future of our national policies. It is to be noticed that the recommendations submitted by the four presidents of the engineering societies were adopted practically in entirety as the "Declaration of the Governors."

We especially appreciate and commend the very active part taken by President Stott, both in bringing about the concerted action by the engineering societies, and also for his personal effort in conjunction with the other presidents in the successful and forceful presentation of the fundamental part that engineering must have in the accomplishment of the objects for which the Conference was called.

WM. MCCLELLAN: The seconding of such a series of resolutions is a mere formality, because it is well known how all engineers feel about it, but it may be well to rehearse and emphasize a few facts in connection with the Conference at Washington.

You probably recall that President Roosevelt some time ago asked for a Conference of representatives from various parts of the United States, which has been popularly called the "Conference of the Governors." Among those invited were the presidents of the four national engineering societies—mining engineers, civil engineers, electrical engineers, and mechanical engineers. The Conference was to consider that great question of what we shall do towards proper conservation of our natural resources. The presidents of the four national engineering societies were invited by President Roosevelt to attend the Conference.

President Stott immediately started to work, at a time when his health was not of the best, to bring the four presidents together to discuss some means of concerted action. It was decided that the influence of the engineering societies of the country could be made of the most importance by preparing a series of recommendations to be presented to the Conference. These recommendations were to be presented by the four presidents, as representing the opinion of 20,000 engineers of this country and at the same time voicing their absorbing interest in the project.

An opportunity to use these recommendations came in a very fortunate way. During the Conference, the governors were asked to prepare a series of resolutions, and they come together without any definite idea as to what to do. At this opportune moment, the recommendations representing the opinions of the engineers of the country were presented, with a remarkable result—the resolutions were taken up by the governors, practically as they were written, the only resolution omitted being one referring to a matter that the Congress had already acted on, and which the governors did not care to discuss, inasmuch as it had had congressional action.

Now, the part that these men played was a very great part. We are accustomed to hear that engineers are rather narrow in their views, and are chiefly valuable for their calculative and inventive ability, rather than for general direction of affairs. It is no small thing, therefore, that the series of resolutions prepared by the four presidents were sufficiently broad and attractive to merit the approbation, and represent the opinion, of such men of large affairs as the governors of the states. It is no small thing that when the resolutions were called for it was found that they were just what was wanted, and were so carefully prepared that they could express the ideas of political representatives of the whole country. It must be acknowledged that this action placed the engineers of the country as a whole in a totally new light; it proved beyond a doubt that engineers can be broad-minded if they will. It is because they did so much to place the engineer in this new light, that we believe the action should be commended, and that President Stott should be especially commended for the unselfishness and intelligence displayed in bringing it about.

Chairman Armstrong: We are very proud of the part our respected president has played in the matter. I understand that this is put before the Institute as a resolution. It is moved and seconded that this resolution be adopted. Is there any discussion? If not, I call for a rising vote— those in favor please rise. [The resolution was carried unanimously.]

President Stott: We have now come to the end of our program for the twenty-fifth Annual Convention of the American Institute of Electrical Engineers. Before announcing the close of the convention, I wish to thank you one and all, the Board of Directors, and every member of it, for hearty cooperation and helpfulness to me during the last year.

University Branches*

BY HENRY H. NORRIS

At the present time practically all of the technical colleges in this country recognize the importance of affiliation with the Institute through local Section and Branch work. The Institute is such an integral part of the educational plan of these colleges that students graduate well informed as to its objects and organization. A reasonable proportion are enrolled as Institute Students, and a few have already achieved the grade of Associate. All of this has come about within a very few years; that is, during and since the presidency of Mr. Charles F. Scott. If the departments of electrical engineering in the technical schools are to do their best for the students, the latter must be encouraged to affiliate with the Institute, preferably through student enrolment at the start. In canvassing this matter with his own students the writer placed before them the following arguments:

WHY TECHNICAL STUDENTS SHOULD ENROLL IN THE INSTITUTE

The American Institute of Electrical Engineers has made the liberal provision that approved Students may enroll at the nominal fee of $3.00 per year, which is construed as a subscription to the Proceedings. In addition to the monthly Proceedings the student receives all of the advantages of the local branch in his vicinity including:

1. Advance copies of the Institute papers.
2. Benefits resulting from the expenditure of the allowance made to the branches from the Institute treasury.
3. Privilege of wearing the Institute Student pin.
4. Privilege of purchasing the Transactions at reduced rates.
5. Stimulation of interest in engineering activity by association with local branches and by identification with the Institute which is the natural focus of the electrical intelligence of the country.

Why Seniors Should Enroll.

They will soon be in active business and need to be familiar with all available engineering information.

---

* Presented at the special session of the delegates of the Sections and Branches at Atlantic City, July 1, 1908.

Why Juniors Should Enroll.

They should by their third year be assuming responsibility in University Branch affairs and receiving stimulus for the advanced work of the fourth year.

Why Sophomores Should Enroll.

They need raw material from which to develop the theory of their engineering courses. The Institute PROCEEDINGS give a perspective view of engineering practice.

Why Freshmen Should Enroll.

The sooner they identify themselves with the center of engineering activity the more interest will they take in their students. While they may not understand every statement made, enough benefit will be received to pay for the effort to grasp the engineering significance of the papers presented. They will realize the necessity for careful attention to the details of their preparatory studies.

The social side of the local branch work is an important feature of student enrolment. A student cannot afford to neglect any opportunity to become acquainted with his fellow-students, his teachers, and the professional engineers in his vicinity. The local branch furnishes such an opportunity.

The fee for student enrolment should not be a consideration in view of the important results which follow. An average student spends at least $500 per year. Of this $3.00 should be set aside for enrolment in the Institute before less efficient expenditures are decided upon.

As would naturally be expected the seniors are those most interested in Branch work. In very few institutions are the freshmen and sophomores enrolled in considerable numbers. Some interest is taken during the junior year, but the burden must necessarily be carried by the upper classmen. The enrolment of underclassmen is of doubtful expediency, but in some cases these men make excellent Branch members. The enrolment of seniors is practically essential if the school makes the proper use of the Institute privileges.

In order to permit the comparison of the conditions existing among the various Branches, the following table has been compiled:

UNIVERSITY BRANCH DATA

Section or Branch	Enrolled A.I.E.E. Students (a)	Probable E.E. Graduates (b)	Probable E.E. Students (c)	Ratio a/b	Ratio a/c
Armour Institute	27	18	150	1.50	0.18
Iowa State College	37	30	265	1.23	0.14
Kan. State Agr. College	19	21	135*	0.91	0.09
Lehigh University	60	18	125	3.33	0.48
Stanford University	24	18	104	1.33	0.23
Lewis Institute	33	20	410	1.65	0.08
Montana Agr. College	9	3	41	3.00	0.22
Penn. State College	—†	44	293		
Purdue University	80	78	469	1.03	0.17
Syracuse University	19	25	130	0.76	0.15
Univ. of Arkansas	6	2	76	3.00	0.08
Univ. of Colorado	13	18	120	0.72	0.11
Univ. of Maine	—	20	72*		
Univ. of Michigan	28	44	170	0.64	0.17
Univ. of Missouri	3	25	200	0.12	0.02
Univ. of Montana	4	5	50	0.80	0.08
Univ. of Texas	27	7	134	3.85	0.20
State Col. of Washington	21	9	50	2.34	0.42
Univ. of Wisconsin	15	40	246	0.38	0.06
Worcester Poly. Inst	47	29	145	1.62	0.32
SECTIONS CONTAINING MANY ENROLLED STUDENTS.					
Urbana	45	32	325	1.41	0.14
Schenectady	24	15	29‡	1.60	0.33
Cincinnati	10	7	45	1.43	0.22
Ithaca	111	105	570	1.06	0.20
Totals of branches reporting enrolled students	662	569	3989	1.16	0.166

* Freshmen not classified (total estimated at 3/2 of upper three classes).

‡ Freshmen and sophomores not included (total estimated at 5/2 of upper two classes).

† Could not be separated this year from E. E. society.

The table shows the approximate number of students enrolled on February 15, 1908, the probable number of electrical engineering graduates at the 1908 commencement, and the approximate total number of students pursuing electrical engineering courses.

As a basis of comparison two ratios have been calculated.

(1) That of enrolled students to probable graduates.

(2) That of enrolled students to total students pursuing electrical courses. The first ratio varies from a maximum of 3.85 to a minimum of 0.38 with an average of 1.16. The second ratio varies between a maximum of 48 per cent and a minimum of 2 per cent, with an average of 16.6 per cent. Assuming that the average represents a fair degree of interest in Institute matters, it furnishes a standard by which each Branch may measure its own activity. In making this comparison it should be borne in mind that the small Branch has an advantage over the large one in that it is more wieldy—the students are better acquainted, and they are in closer contact with their teachers. On the other hand, the large Branch has the enthusiasm of numbers, which is also an important element in maintaining interest. Again, there are local conditions which increase or decrease interest. The best showing in the table is made by those Branches which minister to the social instincts of their members, conspicuous among these being Lehigh and Worcester. The University of Illinois, (Urbana Section), is also very successful in this particular. University Branch work has been the subject of much experimentation which has yielded valuable experience for future guidance. The Branches have not developed exactly as expected, but as they have not been hampered by unnecessary restrictions the growth has been a natural one. The work of the University Branches differs in many details from that of the Sections, and hence must be studied separately. The writer confesses to some disappointment that the original program* has not proved entirely feasible, but this disappointment is due to a previous misunderstanding of the local conditions.

In order to learn the exact present status of University Branch work correspondence has been conducted with all the Branches, and numerical data and detailed suggestions have been obtained. With practically no exception, their experience shows that a presentation of New York papers either entire or in abstract arouses no local enthusiasm.

The reasons for this are:

1. The treatment is frequently too involved to be comprehended by the students.

2. The subject matter does not connect well with the daily experience of the students.

3. Any one topic appeals to but a portion of the student body, just as at New York a small proportion of the Institute membership is interested in any one subject.

The primary function of Branch meetings is to stimulate and develop the students; in other words, it is educational. Therefore whatever is done in these meetings should tend toward the desired end. To be educational, a subject must fit in well with the previous knowledge of the student, and he must be able, without unnecessary effort and with interest, to incorporate the new material into his mental equipment. From this standpoint it is easy to see why some meetings have failed while others have encouragingly succeeded.

The successful meetings are those which:

1. Are as different as possible from regular class exercises.

2. Stimulate active discussion among the students.

3. Bring the audience into contact with real engineering practice.

4. Acquaint the students with the personality of practical engineers.

---

* It was supposed that the abstracting and discussing of New York papers would be a main feature of Branch meetings.

5. Develop the social life of the Branch.

Among the details of successful meetings the most important is the choosing of the speaker. When possible he should be brought from outside the college, or at least from outside the electrical department. The faces, methods, and ideas of the regular teachers become monotonous to the students.

After the choice of speaker comes that of subject, which as a rule may be safely left to the speaker himself. The address should possess the following characteristics:

1. It should indicate a tendency in some line of engineering development.
2. It should be based upon the speaker's own successful experience.
3. It should contain enough detail to be definite and not enough to be tedious.
4. It should appeal to the mind through the eye, as well as ear, by the use of experiments, lantern-slides, charts, and mathematical demonstrations.

The nature and extent of the particular field covered by the lecture should be made real to every intelligent listener. A printed or mimeographed outline or syllabus in the hands of the audience is of great assistance in focusing attention and rendering more permanent the impression made.

The address should be short enough to allow extended discussion, and the speaker's success may usually be measured by the volume and spirit of the discussion which he provokes. Assuming that the subject is well chosen, if no discussion follows the inference is that either the listeners are tired of the topic, or it has not been presented in such a manner as to stimulate them to self-activity.

A skilful combination of recreative features with the more formal exercises is sometimes beneficial. Music is always in order, and light refreshments appear to stimulate mental activity. The responsibility for such entertainment in itself tends to interest students who otherwise might not be induced to attend.

It is obviously not possible in most Branches to obtain outside speakers for every meeting. Three or four are, as a rule, as many as can be secured, both on account of the expense and because speakers are not available. There must, therefore, be a number of meetings in which local talent only is available. At such meetings the presentation of original papers by members of the Branch should be encouraged. Occasional talks by instructors are helpful, if the topics selected are quite foreign to those of the courses given by the same instructors. In these meetings informality tends to put the students at their ease, and encourages them to talk. While the students cannot contribute largely to the practical value of the discussion, unless they have had experience in the particular field covered by the speaker, they are greatly benefited by taking part in it. The instructors in such meetings should make every effort to bring out topics that the undergraduates can understand. In some Branches the use of a question box is very successful in these informal meetings, as the audience usually contains some person qualified to answer any reasonable question that may be asked. The attendance at these meetings must be largely stimulated by advertising, for the reason that there are many rival attractions at technical schools.

A problem which confronts many Branches is to establish and maintain proper relations with other technical societies. There is usually found an electrical society of some sort, as well as organizations of mechanical, civil, and other engineers. While this problem is one for local solution, yet the writer believes that the Institute should be the center of electrical engineering activity outside the class room. Either other electrical societies must be absorbed, or the field of work must be carefully divided with them.

The development which has been outlined indicates a tendency for the Branches to grow away from the Institute. If the meetings are to be occupied entirely with independent papers and discussions, what is to bind the Branches to the main organization? The enrolled students as well as Institute members receive the PROCEEDINGS and the advance copies of papers, and these must be used in some way to form a bond to hold the Branches together, and to the Institute. Experience shows that as a rule the Branch meetings are not stimulated by rehearsing the New York papers and discussion. It seems advisable, therefore, that the Institute papers should be incorporated as far as possible into the text used in regular courses. Several schools are now following this practice, which must become more general if the Institute is to mean what it should to the rising generation of electrical engineers.

The Advantages of Membership in the American Institute of Electrical Engineers*

BY CHARLES B. BURLEIGH

The question has frequently been asked, what advantage is to be derived from membership in the American Institute of Electrical Engineers?

There can be no question as to the duty of every American citizen to support and maintain the Supreme Court of the United States. Can there, therefore, be advanced any legitimate reason as to why it is not a duty that he owes, not only to himself but to each and every one of his associates in the business in which he is engaged, for every electrical engineer to do his utmost to support and maintain a court of last resort, by whom all disputed technical questions in electrical engineering shall be finally settled? To assist so far as in him lies, in removing all electrical work from the region of guesswork to that of certainty, thereby increasing the stimulus to the successful investment of capital in electrical enterprises? To effect a concentration of effort and increased mentality excited by generous rivalry?

With these objects in view the American Institute was formed with the avowed purpose of promoting the arts and sciences connected with the production and utilization of electricity and the welfare of those employed in these industries; by means of meetings for social intercourse, the reading and discussion of professional papers, and the circulation, by means of publications among its Members and Associates, of information thus obtained.

Appreciating this situation, affiliation with the organization is not a question of what benefit will result to the individual, but is a duty he owes to the art, to his associates and to himself, to do everything in his power to aid and assist in the support and maintenance of an institution without which we would all be whirling around in our own little circle, duplicating effort, narrowing the scope of the art and our own fields of usefulness.

The electrical engineer also owes a duty to the public in general, who place in his hands the solving of problems in connection with the details of which they are totally uniformed, and only by placing himself in a position to give them the best information procurable can he be assured of rendering to them full return for the confidence imposed. Again, it is generally conceded by the world at large that the most valuable opinion and judgment on any class of work is that rendered by the leaders in that profession; for which reason the electrical engineer's standing is in a great measure fixed by the recognition of his ability by his associates, and only by an acquaintance with them, thus offering them the opportunity to familiarize themselves with his capabilities, can he establish his standing, and as the best estimate of an engineer as a man and an engineer is the opinion of the members of his own profession, it is his duty to himself, as well as to those from whom he derives his livelihood, that he become known to and acquainted with his associates.

---

* Reprinted from the *Electrical Review*, New York, Aug. 1, 1908.

* * * * *

The benefits to be derived from this association depend largely upon the individual to the extent that if he joins the organization, prompted only by selfish motives, to receive and not to impart benefit, he will receive but little, while he who connects himself with the association, hoping by his work to promote its success, receives in return inestimable benefit from the fact that his work and his contributions tend to make him known to his associates and establish his standing not only among them but in the field at large.

Again, in connection with the different matters brought before the organization for its consideration, he either attends the meeting at which they are presented or reads of them in the TRANSACTIONS, and as reading any similar article presented through the usual channels, forms his own opinions on the subjects treated, but his connection with this association offers him the opportunity to familiarize himself with the opinions of his associates on the subject, and by discussing their opinions, either with them or with himself, arrives at a much broader understanding of the matter.

As the association aims to take up and discuss in its earlier stages of development any and all improvements in the art, the facilities offered enable the membership to keep just a little ahead of the non-members and the public, and prepares them to pass judgment on new devices as soon as their practical consideration becomes desirable.

The scope of the art is continually broadening to such an extent that the necessity for specialization is becoming more and more apparent. The closer the lines are drawn in this direction the more important becomes an organization which offers us the facilities for keeping in touch with the whole general situation, and the more good work can the specialist do for the organization and through it for the art.

Having been connected with the electrical business for some thirty years and with the Institute seventeen years, I feel that I may be pardoned for a suggestion to the older members and a word of advice to the younger members of the profession.

To the older members I would say:

You have seen our profession grow in the last thirty years from the electrician who could set up the gravity cell for the operation of the key and sounder, to the electrical engineer who can carry on his shoulders the water and steam power of the world and deliver its useful energy at any point where commercial conditions make its utilization desirable, outstripping by leaps and bounds all other engineering professions. I may have contributed individually no more than you to this marvelous development, but the association of which I am a member is in a great measure responsible for it, for which reason you owe to it in a large measure the benefit you have and are receiving from it. You would be ashamed to be accused of not paying your just debts. Here is one long overdue, and the quicker you settle by adding your assistance to the good work in becoming a member the sooner you can look everybody in the face and say, " I am in part responsible for the result attained."

To the neophyte I would say:

In any line, individual effort is always praiseworthy, but team work presents the shortest route to success. The sooner you connect yourself with the Institute the quicker you will begin to obtain the best returns from the energy you expend in promoting the interests of the profession you have entered, to the benefit of your employer and to yourself, and if you remain in the business you can look back with pride, in the years to come, to the fact that you have always, from the first moment of entering the profession, lent your best efforts to the best advantage to the advancement of the art.

You may feel that you have completed your education and are now about to reap the benefits. Allow me to disabuse your mind of this idea. Your education has just commenced. Your school and college have provided you with an excellent outfit of tools and you are now about to be taught how to use them to the best advantage. The art is progressing and you will find that new adaptations require new tools not in your chest, and membership in the Institute will tend to keep your tool chest up to date.

Sections and Branches

At a meeting of the Board of Directors on August 14, 1908, authority was granted to the Members and Associates of the Institute at Fort Wayne, Indiana, to establish the Fort Wayne Section, with Mr. E. A. Wagner chairman, and Mr. M. J. Kehoe as secretary.

MINNESOTA SECTION

At the regular monthly meeting of the Minnesota Section held at the office of the St. Paul Gas Light Company on the evening of June 1, 1908, the secretary being absent, Mr. Hibbard was appointed secretary *pro tem* by the chairman. The report of the Committee on Membership was received and read by the secretary, and was as follows:

The committee appointed by the Minnesota Section of the American Institute of Electrical Engineers, to consider the resolutions on the subject of Institute membership, adopted by the Toronto Section, on the 20th of February, 1908, after due consideration of the fact that the requirements for transfer to the grade of Member are extremely rigid and also the fact that the requirements for the grade of Associate are now easy to attain, reports as follows:

The matter of the classification of membership is an important one and deserves consideration.

We heartily endorse the resolution of the Toronto Section.

We suggest that the third classification should have a more distinctive name than that adopted by the Toronto Section.

A motion to accept the report of the committee and to continue the work was carried, it being considered desirable to have this committee carry the work through according to their report, and to take such steps as are necessary to bring about the proposed change in Article II of the Constitution.

The report of the Committee on By-Laws was then read by Mr. Dibble, chairman.

There being no further business to come before the meeting, the discussion of the Institute papers by Messrs. Vaughan and Neall on lightning protection was taken up.

SAN FRANCISCO SECTION

At a meeting of this Section on June 26, 1908, seventy members and guests heard Mr. C. F. Elwell read a paper entitled "Reduction of Iron Ores by Electricity."

ST. LOUIS SECTION

On April 8, 1908, sixty-three members and guests attended a meeting of the St. Louis Section at the Engineer's Club. There was a discussion on the advisability of an Institute intermediate grade of membership, followed by the presentation and discussion of a paper by Mr. E. D. Smith, entitled "Power Generating and Distributing Systems of the United Railways of St. Louis."

Another meeting of this Section, attended by forty-nine members and guests, was held at the Ashley Street plant of the Union Electric Light and Power Company on May 16, 1908. By courtesy of the officials of the light and power company, the entire plant was thrown open for inspection.

KANSAS AGRICULTURAL COLLEGE

At a meeting of this Branch, at Manhattan, Kansas, on June 3, 1908, Mr. W. L. Enfield was re-elected chairman and Mr. W. C. Lane elected secretary to serve until June, 1909.

Associates Elected and Transferred

At a meeting of the Board of Directors at 11 a.m., Friday, August 14, 1908, present President L. A. Ferguson; Past-President H. G. Stott; Vice-Presidents C. C. Chesney, W. C. L. Eglin, and Calvert Townley; Managers P. M. Lincoln, Paul Spencer, H. W. Buck, P. H. Thomas, B. G. Lamme, D. B. Rushmore, W. G. Carlton, C. W. Stone, H. E Clifford; Treasurer G. A. Hamilton, and Secretary R. W. Pope, the following 109 Associates were elected:

ABBOTT, JOHN, General Manager, Jackson Electric Railway Light and Power Co., 317 E. Capitol St., Jackson, Miss.

APPLETON, WILLIAM DAY, Assistant Superintendent of Generating Station, Guanajuato Power and Electric Co., Zamora, Michoacan, Mex.

BADGER, CHARLIE KILGOUR, Student, University of Nevada, Reno, Nev.

BAKER, BURTON EUGENE, Secretary and Engineer, Baker Electric Co., 24 Beach St., Hartford, Conn.

BAKER, JAMES E., Superintendent, Power Transit and Light Co., 904 19th St., Bakersfield, Cal.

BARASH, MILTON D., Engineer, Gray and Barash, 611 Peoples Bank Building, Seattle, Wash.

BARD, JACOB WILLIAM, Electrician, Peoria Gas and Electric Co.; res., 606 State St., Peoria, Ill.

BARNES, DONALD CARTER, Electrical Engineer, Edison Electric Illuminating Co., Brockton; res., 17 Lancaster St., Cambridge, Mass.

BARTLETT, FRANK SARGENT, Tester, General Electric Co.; res., 186 Furman St., Schenectady, N. Y.

BAUM, HARRY, Settlement Worker, University Settlement; res., 130 East 115th St., New York City.

BENNETT, ALAN MARION, Assistant to Chief Engineer, The C. & C. Electric Co.; res., 34 Clark St., Westfield, N. J.

BERNSTEIN, FRITZ, Assistant to Manager, Grand Island Electric Co.; res., 503 W. Division St., Grand Island, Neb.

BLOCK, MARCEL, Superintendent Public Lighting, Mexican Light and Power Co., Mexico City, Mex.

BLUM, GEORGE JACOB, Shop Superintendent, General Electric Co.; res., 331 Hansberry St., Germantown, Philadelphia, Pa.

BRAGG, ROY COLUMBUS, Power House Foreman, Pacific Gas and Electric Co., Colgate via Dobbins, Cal.

BRANDON, EDGAR THOMAS JOHN, Designer, Hydro-Electric Power Commission of Ontario; res., 150 Dowling Ave., Toronto, Ont.

BRIDGES, JAMES EDWIN, Consultor in Engineering Department, Westinghouse Electric and Mfg. Co., San Francisco; res., 2528 Central Ave., Alameda, Cal.

CLARKE, FRANK T., Inspecting Engineer, Commonwealth Edison Co., 139 Adams St.; res., 994 Warren Ave., Chicago, Ill.

COHN, CLARENCE A., Superintendent, Power Stations, Utah Light and Railway Co., 670 E. So. Temple St., Salt Lake City, Utah.

COOK, EDSON WILEY, Student, Harvard University, Cambridge; res. 10 Wise St., Jamaica Plain, Mass.

COOLEY, GEORGE R., Member of Firm, Buxbaum and Cooley, Engineers, 2123 42d Ave., S. W., Seattle, Wash.

CORDES, HENRY G., Electrical Draftsman, U. S. Navy Yard, Puget Sound; res., Bremerton, Washington.

DANFORTH, RICHARD EUGENE, General Manager, Public Service Railway Co. of N. J., 7 Central Ave., Newark, N. J.

DARRALL, CHARLES HENRY, Engineer of Tests, Canadian Westinghouse Co., 135 Main St. West, Hamilton, Can.

DEAL, KARL EDWARD, Testing Department, General Electric Co.; res., 341 Summit Ave., Schenectady, N. Y.

DURBROW, WILLIAM, Engineer, Orr Water Light and Power Co., 1502 Chronicle Bldg., San Francisco, Cal.

Dobler, Joseph, Electrician, Westinghouse Electric and Mfg. Co.; New York City res., 341 43d St., Brooklyn, N. Y.

Dudley, Adolphus Mansfield, Engineer, in charge Induction Motor Design, Westinghouse Electric and Mfg. Co., Pittsburg Pa.

Eaton, Eugene Courtlandt, Draftsman, Montreal Light, Heat and Power Co.; res., 22 Holton Ave., Westmount, Montreal, Que.

Egan, Louis Henry, Resident Engineer, Eastern Michigan Edison Co., Detroit, Mich.

Eichel, Eugene, Consulting Engineer, 106 Alte Takobstr, Berlin, S. W., Germany.

Fellows, Ernest Roslyn, Student, New Hampshire College, Durham; res., 4 Gill St., Exeter, N. H.

Fenner, Robert Coyner, District Manager, Cutler-Hammer Mfg. Co., 176 Federal St., Boston; Mass.

Ferris, Thomas, of Ferris Bros., Osage, Ia.

Furness, Douglas Lyle, Construction Foreman, General Electric Co., Kendallville, Ind.; res., Salem, Mass.

Furthman, William N., Telephone Engineer, Western Electric Co.; res., 1023 Foster Ave., Chicago, Ill.

Gardiner, Henry Alfred, Electrical Engineer, Chicago, Burlington and Quincy R.R., 209 E. Adams St.; res., 24 Evergreen Ave., Chicago, Ill.

Gaus, Frederick G., Chief Electrician, Metropolitan Opera House, res., 517 W. 134th St., New York City.

Geiser, Joseph Funk, Consulting Engineer, 127 N. Church St., Waynesboro, Pa.

Graf, Samuel Herman, Graduate Student, Oregon Agricultural College, Corvallis, Ore.

Grondahl, Lars Olai, Student, Johns Hopkins University, Baltimore, Md.

Heckshher, Otto, Telegraph Engineer, Department of Federal Telegraphs; res., 11 Calle Industria, Mexico City, Mex.

Heidenreich, Allan Harlan, Cincinnati and Suburban Bell Telephone Co., 316 Vine St., Cincinnati; res., Madisonville, O.

Hepburn, Frederick Taylor, District Manager, Ohio Electric Railway Co.; res., 569 West Spring St., Lima, Ohio.

Higbie, Henry Harold, Instructor Electrical Engineering, University of Michigan; res., 1109 East University Ave., Ann Arbor, Mich.

Hines, George Ernst, Chief Electrical Engineer, Burns-McDonnell, 823 Scarritt Building, Kansas City, Mo.

Hollinger, Edwin Kirkman, Draughtsman, New York City Railway Co.; res., 53 West 95th St., New York City.

Kato, Shizuo, Electrical Engineer, Electrical Department of Mitsubishi, Dockyard and Engine Works, Kobe, Japan.

Keifer, Harold Neil, Telephone Switchboard Engineer, Western Electric Co., 2789 Kenmore Ave., Chicago, Ill.

Kelley, Will G., Inspector, Commonwealth Edison Co., 139 Adams St.; res., 5610 Madison Ave., Chicago, Ill.

Klemm, John, Station Engineer, Mexican Light and Power Co., Necaxa, Puebla, Mex.

Knox, James Mason, Technical Editor, General Electric Co.; res., 1205 Union St., Schenectady, N. Y.

Koganey, Harumasa, Shibaura Engineering Works, Shibaku, Tokyo, Japan.

Liggett, William Edwin, Engineer, Stantonville Telephone Co., Hamburg, Tenn.

Lippelt, Hans Bernhard, Engineer, General Electric Co.; res., 2 Heinrich St., Meerane, Saxony, Germany.

Lippincott, Andrew Fuller, Foreman of Construction, General Electric Co., 203 Trust Building, Charlotte, N. C.

Lloyd, Morton Githens, Assistant Physicist, Bureau of Standards, Washington, D. C.; res., Philadelphia, Pa.

Lloyd, Sherman Coxe, Student, Swarthmore College, Pa.; res., 1002 W. 10th St., Wilmington, Del.

Loew, Edgar A., Instructor in Electrical Engineering, University of Wisconsin; res., 412 Murray St., Madison, Wis.

Martindale, James Joseph, Chief Engineer, Northern Construction Co., Lansingh, Mich.

Mayo, Wallace Julius, Foreman, Interior Construction Department, Boston Elevated Railway Co.; Boston, Mass.

McCarthy, Joseph Bartholemew, Erecting Engineer, Westinghouse Electric and Mfg. Co., 129 Conduit St., Annapolis, Md.

Mersereau, Van Vorst, Station Operator, Mexican Light and Power Co., Mexico City, Mex.

Mitchell, Jay Gordon, Electrical Engineer, The North Electric Co.; res., 2180 E. 97th St., S. E., Cleveland, O.

Motz, Jacob Francis, Electric Controller and Mfg. Co., 515 Frick Building; res., 6 Buffalo St., Pittsburg, Pa.

Muhlfeld, John Erhardt, General Superintendent, Motive Power, Baltimore and Ohio R.R. Co., 2214 Eutaw Place, Baltimore, Md.

Mullhaupt, Alfred, Jr., Student, Pennsylvania State College; res., St. Marys, Elk Co., Pa.

Newhard, Franklin S., Foreman, Testing Department, Burke Electric Co.; res., 920 Cranberry St., Erie, Pa.

Obenshain, Archie Woods, Jr., Electrical Engineer, American Iron and Steel Mfg. Co., Lebanon, Pa.

Ota, Toshiyuki, Electrical Engineer, Fuji Cotton Spinning Mill Co., Shizuokaken, Japan.

Painter, Harold Rissel, Assistant Operator, Sub Station, Philadelphia Rapid Transit Co., 6531 Berdan St., Philadelphia, Pa.

Payor, Joseph Paul, Vice President and General Manager, Damm Electrical Co., Flatiron Building; res., 465 West 131st St., New York City.

Pircher, Frank, Assistant Electrical Superintendent, New York Edison Co.; res., 339 East 140th St., New York City.

Pope, Chester Couch, Student, Harvard University, Cambridge; res., 79 Lothrop St., Beverly, Mass.

Powell, Frederick Herbert, Box 217, Germiston, Transvaal, So. Africa.

Price, William Herbert, Salesman, Power and Mining Department, General Electric Co., Chicago, Ill.

Proctor, Carroll Leigh, Railway Department, General Electric Co.; res., 35 N. Wendell Ave., Schenectady, N. Y.

Ramstad, Albert George, Superintendent of Construction, Pacific Gas and Electric Co., San Jose, Cal.

Reed, Norman Winfield, Electrical Inspector, Board Fire Underwriters; res., 2120 Kittridge St., Berkeley, Cal.

Reed, Otto A., Sales Engineer, Fairbanks Morse and Co.; res., 1883 Kenmore Ave., Chicago, Ill.

Robbins, Harris A., Assistant Electrical Engineer, Brooklyn Rapid Transit Co., 85 Clinton St., Brooklyn, N. Y.

Rogers, John S., Salesman, Western Electric Co. Pittsburg, Pa.; res., Corry, Pa.

Sauerhering, Richard Paul, Instructor in Mechanical Engineering, Oklahoma Agricultural and Mechanical College, Stillwater, Okla.

Schmidt, John M., Electrical Engineer, and Yakima Valley Transportation Co., North Yakima, Wash.

Schneider, William Henry, Construction man, Long Island Railroad Co., Broadway and Union Ave., Ozone Park, L. I., N. Y.

Severson, Albert Maurice, Telephone Engineer, The Monson Automatic Telephone Co., North St. Paul, Minn.

SHAFER, JAMES C. FORSYTHE, Civil Engineer and Superintendent of Construction, Quartermaster's Department U. S. A. San Juan, Porto Rico.

SHAFF, SAMUEL EDWIN, Electrician, State University of Iowa. Iowa City, Ia.

SMITH, HARVEY ELLSWORTH, Chief Engineer of Power Houses, Terre Haute, Indianapolis and Eastern Traction Co., Terre Haute, Ind.

STEELE, HARRY GARFIELD, Member of Firm, Pittsburg Transformer Co.; res., Kennedy Ave., North Side, Pittsburg, Pa.

STEWART, STANLEY IRVINE, Chief Engineer, Willamette Valley Co., 519 W. 5th St., Albany, Ore.

STREET, EDWARD TATUM, Salesman, Westinghouse Electric and Mfg. Co., 1420 171 LaSalle St., Chicago, Ill.

SULLIVAN, FRANK, JR., Investigator, New York and New Jersey Telephone Co.; res., 1508 Bedford Ave., Brooklyn, N. Y.

SWINBURNE, EDWARD D., Electrical Engineer, National Biscuit Co., 409 W. 15th St.; res., 371 W. 117th St., New York City.

THOMPSON, ROY EDWIN, Assistant Superintendent, San Diego Consolidated Gas and Electric Co., San Diego, Cal.

THORNTON, GEORGE A., Electrical Engineer, General Electric Co.; res., 543 Rugby Road, Schenectady, N. Y.

THUMMEL, WILLIAM G., Chief Engineer, Bartlesville Inter-Urban Railway, Bartlesville, Okla.

TILLSON, EDWIN DELEVAN, Electrical Engineer, with G. M. Gest, 277 Broadway, New York City.

TURNER, CLARENCE PORTER, Engineer, General Electric Co.; res., 117 Glenwood Boulevard, Schenectady, N. Y.

TURNER, RICHARD ALBERT, Superintendent of Construction, F. T. Ley and Co., Inc.; res., 284 Dickinson St., Springfield, Mass.

VOGE, ADOLF LAW, Assistant Editor and Technical Director, Concilium Bibliographicum, Hofstrasse, Zurich, Switzerland.

WADDELL, HOMER A., General Superintendent, Pittsburg and Allegheny Vy Ry. Leechburg, Pa.

WIELAND, ALBERT EDGAR, Consulting and Contracting Engineer, Wenatchee Wash.

WILLEY, VERNON JUSTIN, Instructor Electro-Therapeutics and X-ray, University of Michigan, 308 E. Madison St., Ann Arbor, Mich.

WILSON, CHARLES JASPER, Superintendent of Electrical Department, Oakland Gas Light and Heat Co., Oakland, Cal.; res., Piedmont, Cal.

WOOD, ARCH K., Engineer, G. R. Wood, Consulting Engineer, 1207 Park Building, Pittsburg, Pa.

WOOD, FRANKLIN PORTER, Superintendent, Black Hills Traction Co., Deadwood, S. D.

WOODWARD, EDWARD BLACK, Shift Engineer, Mexican Light and Power Co., Ltd., Necaxa, Puebla, Mex.

ZIEGLER, ALFRED THEOPOLUS, Electrical Engineer, Central District and Printing Telegraph Co.; res., 2121 Federal St. Extension North Side, Pittsburg, Pa.

The following members were transferred to the grade of Member:

JOSEPH AUKEN THALER, Professor of Electrical Engineering, Montana Agricultural College, Bozeman, Montana.

CHARLES EDWARD LORD, Manager Patent Department, The Bullock Electric Mfg. Co., and Electrical Patent Attorney, Allis-Chalmers Co., Norwood, Ohio.

WILLIAM NELSON GOODWIN, JR., Chief Electrical Engineer, Western Electrical Instrument Co., East Orange, N. J.

HENRY DUVALL JAMES, Electrical Engineer with Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

ARTHUR WILLIAMS, General Inspector, The New York Edison Company, 55 Duane Street, New York.

Personal

Mr. C. E. Chatfield is now taking the student course at the Western Electric Company's Hawthorne plant. His mail address is Riverside, Illinois.

Major Zalinski, U. S. A., retired, has become president of the Bureau of Illuminating Engineering, 437 Fifth Avenue, New York City.

Mr. G. A. Anderegg has resigned his position in the Ohio State University, and is now employed in the physical laboratory of the Western Electric Company, New York City.

Mr. S. A. Williams has taken charge of the Hazlehurst Mississippi Municipal Light and Water Works plant, which he will enlarge and rebuild from time to time as conditions require.

Mr. H. H. Vrooman has left the employ of the Mexican Light & Power Co. of Mexico City, and is now in the employ of the Cia, Electrica e Irrigadora of the State of Hidalgo, Mexico.

Mr. Alfred E. Braddell, of the Sprague Electric Company, has been transferred from their Philippine office to the Chicago office, where he will have charge of their conduit department.

Mr. E. Le C. Hegeman has returned after a year's leave of absence, to resume his work with Mr. J. K. Robinson, representing the Westinghouse interests on the west coast of South America.

Mr. Herbert W. Andrews, for over two years connected with the transformer engineering department of the General Electric Company at the Schenectady works, has been transferred to the Pittsfield works.

Mr. J. M. Campbell is now president and general manager of the Buffalo, Lockport and Rochester Railway Company, an electric line now being built from Rochester to Lockport, with connections to Buffalo.

Mr. F. R. Phillips, formerly engineer in charge of railway development work of The Ohio Brass Company, has accepted the position of master mechanic of the Municipal Traction Company, Cleveland, Ohio.

Mr. B. T. Viall, formerly electrical superintendent for the Arizona Smelting Company at Humboldt, Arizona, has accepted the position of chief electrician with the Calumet and Arizona Mining Company at Bisbee, Arizona.

Mr. Taylor S. Curtis, formerly located at Annapolis, Maryland, in connection with the single-phase installation for the Maryland Electric Railways Company, has accepted the position of instructor in physics in the University of Cincinnati.

Mr. A. S. Kalenborn has returned from Seattle, Washington, where he was in charge of the office of F. G. Baum & Company, to the main office at San Francisco, Cal. The work the company was doing at Seattle having been completed, the office has temporarily been discontinued.

Mr. P. E. Mitchell, for the last four years general superintendent of the Knoxville Railway and Light Company has been appointed superintendent of power of the Brimingham Railway Light & Power Company, in direct charge of the power station and sub-stations at Birmingham, Ala.

Mr. A. Bement, consulting engineer, giving special attention to problems concerning coal production and utilization, furnace and boiler plant design, gas producer practice, and allied metallurgical branches of engineering, has moved to enlarged quarters at 2114 Fisher Building, Chicago.

Mr. Wm. H. Bristol is now giving his entire attention to the management of the business of The Bristol Company, which includes the business of the Wm. H. Bristol Electric Pyrometer Company, formerly located at New York. His headquarters will be at Waterbury, Connecticut, until further notice.

Mr. Domingo L. Monjo, who has been representing the Westinghouse Electric and Manufacturing Company in Northern Mississippi, has resigned from that company to assume the management of the Cleveland Light and Power Company, at Cleveland, Mississippi, which property he recently purchased.

Mr. William van den Heuvel is now located at Los Angeles, due to the removal of the office of the United States Reclamation Service from Madison, Wisconsin, to Los Angeles. He expects to remain in the service of the government as electrical engineer and assistant to the chief electrical engineer, Mr. O. H. Ensign.

The New England Insurance Exchange of which Mr. C. M. Goddard is secretary has moved its offices from 55 Kilby Street to the Oliver Building, 141 Milk Street, Boston, Mass. Mr. Goddard is also Secretary of the Underwriters' National Electric Association, and President of the National Fire Protection Association.

Mr. A. J. Quigley, formerly assistant superintendent for J. G. White & Company on reconstruction of Tri-City public utility properties of Rock Island, Moline and Davenport, is now at Seattle, Washington, assistant under the Director of Works of the Alaska-Yukon-Pacific Exposition, being principally concerned with the electrical layout required for illumination, power, etc.

Mr. H. D. Larrabee has severed his connection with the National Light & Power Company, as electrical engineer, in order to engage in general engineering work and contracting business with the Green Mountain Electric Company at Montpelier, Vermont, as member of the firm. They will do a general consulting business, also a line of general construction work, including interior work and plant designs and construction.

Mr. S. P. Grace, formerly chief engineer of the Central District & Printing Telegraph Company of Pittsburg, has been promoted to the position of general superintendent of plant, and will have charge of the designing, construction, maintenance and inspection of the company's plant, including real estate. This department will comprise what are now the engineering, construction, maintenance, right-of-way and Morse service departments.

Books Received

Practical Irrigation, Its Value and Cost. By Aug. J. Bowie, Jr. 232 pages. Illustrated. New York: McGraw Publishing Company. 1908. Price, $3.00 net.

Contents.—Chapter I.—What Irrigation has Accomplished. II.—Units in Use. III.—Methods of Irrigation in Use. IV.—Evaporation. V.—Different Sources of Water Supply. VI.—Methods and Appliances for Obtaining Water. VII.—Wells. VIII.—Pumps and Pumping Machinery. IX.—Irrigation Near Bakersfield. X. Economic Limit of Irrigation. XI.—Earth Tanks. XII.—Large Artificial Reservoirs. XIII. - Large Reservoirs for the Storage of Artesian Water. XIV.—Economic Use of Reservoirs and Tanks. Appendix A. Appendix—Circular Embankments. Index.

Telephone Law. The Organization and Operation of Telephone Companies. By A. H. McMillam, A.B., L.L.B. 331 pages. New York: McGraw Publishing Company. 1908. Price, $3.00 net.

Contents.—Chapter I.—The Choice of a State from which to Secure a Charter. II.—What the Charter Should Contain. III.—Organization, Code of By-laws and Regulations. IV.—Keeping the Records of the Corporation. V.—Federal, State and Municipal Franchises. VI.—Ordinances, Commonly Called Franchises, Providing the Regulations under which Telephone Companies are Permitted to Build Lines in Municipalities. VII.—Rates, Rentals and Charges. VIII.—Rights of Way and Private Owners. IX. —Eminent Domain. X.—Location of Poles and Wires. XI.—Respective Rights of Telephone Companies and Electric Light and Traction Companies. XII.—Building through Established Lead—Joint Occupation of Pole Lines. XIII.—Subways and Underground Conduits. XIV.—Cutting and Trimming Trees. XV.—Financing Plans and Securities. XVI.—Paragraph. XVII. —Taxation. XVIII.—Questions of Damages. XIX.—Contracts, Fire Insurance, Employers' Liability Insurance, Regulations and House Moving. Appendix of Forms.

Electrical Contracting. Shop System, Estimating, Wiring Construction Methods, and Hints on Getting Business. By Louis J. Auerbacher. 155 pages. Illustrated. New York: McGraw Publishing Company. 1908. Price, $2.00 net.

Contents.—Chapter I.—Shop System for Electrical Contractors. II.—Estimating on Contract Work. III.—Wiring Systems. IV.—Exposed Circuit Wiring. V.—Wiring with Wooden Moldings. VI.—Wiring with Flexible Conduit and Armored Cable. VII.—Wiring with Iron Conduit. VIII.—Residence Wiring. IX.—Wiring for Direct-Current and Alternating-Current Motors. X.—Installation and Operation of Direct-Current Belted Generators and Switchboards. XI.—Electric Signals and Telephone Systems. XII.—Special Lighting Devices. Index.

The Plane Table and Its Use in Surveying. By W. H. Lovell. 49 pages. Illustrated. New York: McGraw Publishing Company. 1908. Price, $1.00 net.

Contents.—Introduction. Forms of Plane Tables. Adjustment of the Alidade. Plane Table Triangulation. The Three-Point Problem. The Two-Point Problem. Centering the Plane Table over the Station. Vertical Angulation. Signals Land Surveys. Plane-Table Traverse. Projections. Conclusion. Index.

Notes on Hydro-Electric Developments. By Preston Player. 68 pages. Illustrated. New York: McGraw Publishing Company. 1908. Price, $1.00 net.

Contents.—Chapter I.—Preliminary Determinations. II.—Methods of Procedure. III.—Engineering Examination. IV.—The Extent of the Market for Energy. V.—Cost of Energy Manufacture. VI.—Central Station Economics. VII.—Sale of Electric Energy. VIII.—Primary and Secondary Powers. IX.—Capital Costs.

Electrical Engineer's Pocket-Book. A Handbook of Useful Data for Electricians and Electrical Engineers. By Horatio A. Foster. 1599 pages. Illustrated. Fifth edition, completely revised and enlarged. New York: D. Van Nostrand Company. 1908. Price, $5.00.

Contents. — Electrical Section. — Symbols. Units, Instruments. Measurements. Magnetic Properties of Iron. Electromagnets. Properties of Wires and Cables. Properties of Conductors Carrying Alternating Currents. Dimensions of Conductors for Distribution Systems. Standard Symbols for Wiring Plant as Adopted by the National Electrical Contractors' Association. Underground Conduits and Construction. Cable Testing. Direct-Current Dynamos and Motors. Tests of Dynamos and Motors. Alternating-Current Machines. The Static Transformer. Standardization Rules of the American Institute of Electrical Engineers. Electric Lighting. Illuminating Engineering. Electric Railways. Deterioration of Underground Metals Due to Electrolytic Action. Transmission of Power. Storage Batteries. Switchboards. Electricity Meters. Telegraphy. Wireless Telegraphy. Telephony. Uses of Electricity in the United States Army. Electricity in the United States Navy. Resonance. The Electric Automobile. Electrochemistry —Electrometallurgy. X-Rays. Electric Heating, Cooking and Welding. Mechanical Section. Foundations and Structural Materials. Steam. Water-Power. Shafting, Pulleys, Belting, Rope-Driving. Miscellaneous Tables. Power Required to Drive Machinery, Shops, and to do Various Kinds of Work.

Metric Weights with English Equivalents. By Hugh P. McCartney. 83 pages. London: E. & F. N. Spon, Ltd. New York: Spon & Chamberlain. 1907. Price, 50 cents.

Contents.—Avoirdupois Weight. Kilos. Troy Weight.

Electricity in Agriculture and Horticulture. By Prof. S. Lemstrom. Illustrated. 72 pages. London: "The Electrician" Printing and Publishing Company, Ltd. New York: The D. Van Nostrand Co. Price, $1.50 net.

Officers and Board of Directors, 1908-1909

PRESIDENT

LOUIS A. FERGUSON, Chicago, Ill.

JUNIOR PAST-PRESIDENTS.

SAMUEL SHELDON, Brooklyn, N. Y.
HENRY GORDON STOTT, New York, N. Y.

VICE-PRESIDENTS

JAMES G. WHITE, New York, N. Y.
W. C. L. EGLIN, Philadelphia, Pa.

CUMMINGS C. CHESNEY, Pittsfield, Mass.
BANCROFT GHERARDI, New York, N. Y.
CALVERT TOWNLEY, New Haven, Conn.

MANAGERS

JOHN J. CARTY, New York, N. Y.
A. M. SCHOEN, Atlanta, Ga.
PAUL M. LINCOLN, Pittsburgh, Pa.
PAUL SPENCER, Philadelphia, Pa.

MORGAN BROOKS, Urbana, Ill.
HAROLD W. BUCK, New York, N. Y.
PERCY H. THOMAS, Montclair, N. J.
BENJAMIN G. LAMME, Pittsburgh, Pa.

DAVID B. RUSHMORE, Schenectady, N. Y.
W. G. CARLTON, New York N. Y.
CHARLES W. STONE, Schenectady, N. Y.
H. E. CLIFFORD, Boston, Mass.

TREASURER

GEORGE A. HAMILTON, New York, N. Y.

SECRETARY

RALPH W. POPE, New York, N. Y.

PAST-PRESIDENTS

T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
ALEX. GRAHAM BELL, 1891-2.
FRANK J. SPRAGUE, 1892-3.
EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS B. CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1901.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, JR., 1904.5.
SCHUYLER S. WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY GORDON STOTT, 1907-8.

ASSISTANT SECRETARY

FREDERICK L. HUTCHINSON,
33 West 39th Street, New York, N. Y.

GENERAL COUNSEL

PARKER and AARON,
52 Broadway, New York, N. Y.

Standing Committees

EXECUTIVE COMMITTEE

LOUIS A. FERGUSON, Chairman.
139 Adams St., Chicago, Ill.
RALPH W. POPE, New York.
GEORGE A. HAMILTON, New York.
CALVERT TOWNLEY, New Haven, Conn.
C. C. CHESNEY, Pittsfield, Mass.
WM. C. L. EGLIN, Philadelphia, Pa.
JOHN J. CARTY, New York.

FINANCE COMMITTEE

CALVERT TOWNLEY, Chairman.
Consolidated Railway Co., New Haven, Conn
HAROLD W. BUCK, New York.
BANCROFT GHERARDI, New York.

LIBRARY COMMITTEE

EDWARD CALDWELL, Chairman.
239 W. 39th St., New York.
MAX LOEWENTHAL, New York.
PHILIP TORCHIO, New York.
H. E. CLIFFORD, Boston, Mass.
W. G. CARLTON, New York.

MEETINGS AND PAPERS COMMITTEE

A. H. ARMSTRONG, Chairman.
Schenectady, N. Y.
C. E. SKINNER, Pittsburgh, Pa.
RALPH D. MERSHON, New York.
H. H. NORRIS, Ithaca, N. Y.
BION J. ARNOLD, Chicago, Ill.
JOHN J. CARTY, New York.

EDITING COMMITTEE

GEORGE F. SEVER, Chairman.
Columbia University, New York
A. H. ARMSTRONG, Schenectady, N. Y.
SAMUEL SHELDON, Brooklyn, N. Y.

BOARD OF EXAMINERS

HAROLD W. BUCK, Chairman.
49 Wall St., New York.
H. H. BARNES, JR., New York.
MAURICE COSTER, New York.
D. C. JACKSON, Boston, Mass.
W. G. CARLTON, New York.

STANDARDS COMMITTEE

SAMUEL SHELDON, Chairman.
Polytechnic Institute, Brooklyn, N. Y.
S. W. STRATTON, Washington, D. C.
C. P. STEINMETZ, Schenectady, N. Y.
CLAYTON H. SHARP, New York.
J. W. LIEB, JR., New York.
B. A. BEHREND, Milwaukee, Wis.
A. E. KENNELLY, Boston, Mass.
CHARLES F. SCOTT, Pittsburgh, Pa.
GANO DUNN, Ampere, N. J.

CODE COMMITTEE

F. A. C. PERRINE, Chairman.
60 Wall St., New York.
W. H. BLOOD, JR., Boston, Mass.
H. B. GEAR, Chicago, Ill.
ARTHUR WILLIAMS, St. Louis, Mo.
WASHINGTON DEVEREAUX, Phila., Pa.
C. W. STONE, Schenectady, N. Y.
H. S. WARREN, New York.
JOSEPH C. FORSYTH, New York.
FARLEY OSGOOD, Newark, N. J.

LAW COMMITTEE

H. G. STOTT, Chairman.
600 West 59th St., New York.
SAMUEL SHELDON, Brooklyn, N. Y.
J. W. LIEB, JR., New York.
A. E. KENNELLY, Boston, Mass.
CHARLES F. SCOTT, Pittsburgh, Pa.

SECTIONS COMMITTEE

PAUL SPENCER, Chairman.
Broad and Arch Sts., Philadelphia, Pa
H. H. NORRIS, Ithaca, N. Y.
D. B. RUSHMORE, Schenectady, N. Y.
PAUL M. LINCOLN, Pittsburgh, Pa.
H. R. KING, Chicago, Ill.

Special Committees

RAILWAY COMMITTEE

(Sub-com. of Meetings and Papers Committee.)

BION J. ARNOLD, Chairman.
181 La Salle St., Chicago, Ill.
GEORGE GIBBS, New York.
N. W. STORER, Pittsburgh, Pa.
H. ST. CLAIR PUTNAM, New York.
E. H. ANDERSON, Schenectady, N. Y.

EDUCATIONAL COMMITTEE

(Sub-com. of Meetings and Papers Committee.)

HENRY H. NORRIS, Chairman.
Cornell University, Ithaca, N. Y
CHARLES F. SCOTT, Pittsburgh, Pa.
C. O. MAILLOUX, New York.
GANO DUNN, Ampere, N. J.
H. E. CLIFFORD, Boston, Mass.
CHARLES P. STEINMETZ, Schenectady, N.Y.

HIGH-TENSION TRANSMISSION COMMITTEE

RALPH D. MERSHON, Chairman.
60 Wall St., New York.
PAUL M. LINCOLN, Pittsburgh, Pa.
W. S. MOODY, Schenectady, N. Y.
C. C. CHESNEY, Pittsfield, Mass.
W. N. RYERSON, Niagara Falls, N. Y.

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES

H. G. STOTT, Chairman.
600 West 59th St., New York.
CHARLES H. PORTER, Boston, Mass.
W. H. BLOOD, JR., Boston, Mass.
W. L. ABBOTT, Chicago, Ill.
JOHN H. FINNEY, Atlanta, Ga.
P. G. GOSSLER, New York.
F. A. C. PERRINE, New York.

Sections and Branches—Directory

Name and when Organized.	Chairman.	Secretary.	Regular Meeting.
SECTIONS			
Atlanta............Jan. 19, '04	J. H. Finney.	G. J. Yundt.	1st Tuesday.
Baltimore.........Dec. 16, '04	J. B. Whitehead.	C. G. Edwards.	2d Friday.
Boston............Feb. 13, '03	A. E. Kennelly.	A. L Pearson.	3d Wednesday
Chicago..................1893	H. R. King.	J. G. Wray.	1st Tuesday after N. Y. meeting.
Cincinnati.........Dec. 17, '02	A. G. Wessling.	A. C. Lanier.	3d Wednesday.
Cleveland.........Sept. 27, '07	Henry B. Dates.	F. M. Hibben.	3d Monday.
Columbus.........Dec. 20, '03	R. J. Feather.	H. L. Bachman.	1st Wednesday.
Fort Wayne.......June 12, '08	E. A. Wagner.	M. J. Kehoe.	
Ithaca............Oct. 15, '02	E. L. Nichols.	H. H. Norris.	1st Friday after N. Y. meeting.
Los Angeles........May 19, '08			
Mexico...........Dec. 13, '07	R. F. Hayward.	F. D. Nims.	
Minnesota..........Apr. 7, '02	E. H. Scofield.	A. L. Abbott.	2d Monday after N. Y meeting.
Norfolk...........Mar. 13, '08	R. R. Grant.	F. W. Walter.	
Philadelphia.......Feb. 18, '03	Paul Spencer.	H. F. Sanville.	2d Monday.
Pittsburg..........Oct. 13, '02	C. E. Skinner.	R. A. L. Snyder.	1st Wednesday.
Pittsfield..........Mar. 25, '04	J. Insull.	H. L. Smith.	3d Friday.
San Francisco......Dec. 23, '04	A. M. Hunt.	G. R. Murphy.	4th Friday.
Schenectady.......Jan. 26, '03	D. B. Rushmore.	J. M. Knox.	Every Friday.
Seattle............Jan. 19, '04	J. H. Harisberger.	George H. Moore.	3d Saturday.
St. Louis..........Jan. 14, '03	A. S. Langsdorf.	H. I. Finch.	2d Wednesday
Toledo............ June 3, '07	C. R. McKay.	Geo. E. Kirk.	1st Friday.
Toronto..........Sept. 30, '03	W. A. Bucke.	W. G. Chace.	2d Friday.
Urbana...........Nov. 25, '02	J. M. Bryant.	E. B. Paine.	1st Wednesday after N.Y. meeting.
Washington, D. C..Apr. 9, '03.	Philander Betts.	L. D. Bliss.	2d Wednesday.

Sections and Branches—Directory

Name and when Organized.	Chairman.	Secretary.	Regular Meeting.
BRANCHES			
Univ. of Arkansas..Mar. 25, '04	M. F. Thompson.	C. R. Rhodes.	Alternate Mondays.
Armour Institute...Feb. 26, '04	T. C. Oehne, Jr.	J. E. Snow.	1st & 3d Thursdays.
Univ. of Cincinnati..Apr. 10, '08	C. R. Wylie.	C. C. Buchanan.	
Univ. of Colorado..Dec. 16, '04	H. H. Watters.	L. D. Jones.	1st and 3d Wednesdays.
Iowa State College..Apr. 15, '03	F. A. Fish.	Adolph Shane.	1st and 3d Wednesdays.
Kansas State Agr. Col., Jan. 10, '08	W. L. Enfield.	W. C. Lane.	
Univ. of Kansas....Mar. 18, '08	Martin E. Rice.	H. P. Broderson.	Alternate Thursdays
Lehigh University..Oct. 15, '02	H. O. Stephens.	J. A. Clarke, Jr.	2d Tuesday.
Lewis Institute.....Nov. 8, '07	W. H. Hayes.	P. B. Woodworth.	2d Wednesday.
Univ. of Maine.....Dec. 26, '06		Gustav Wittig.	
Univ. of Michigan..Mar. 25, '04	C. M. Davis.	H. F. Baxter.	1st and 3d Wednesdays.
Univ. of Missouri..Jan. 10, '03	H. B. Shaw.	H. D. Carpenter.	1st and 3d Fridays.
Univ. of Montana..May 21, '07	Robert Sibley.	S. R. Inch.	1st Thursday.
Montana Agr. Col..May 21, '07	B. S. Hind.	J. A. Thaler.	1st Friday.
Univ. of Nebraska..Apr. 10, '08	George H. Morse.	L. E. Hurtz.	
Ohio State Univ....Dec. 20, '02	F. W. Funk.	F. C. Caldwell.	Alternate Wednesdays.
Oregon State Agr. Col., Mar. 24, '08	E. V. Hawley.	E. C. Wiggin.	
Penn. State College.Dec. 20, '02	D. R. Simpson.	C. D. Preston.	Every Wednesday
Purdue University..Jan. 26, '03	J. W. Esterline.	H. T. Plumb.	Every Tuesday.
Stanford Univ......Dec. 13, '07	W. C. North.	A. J. Gowan.	
Syracuse Univ.....Feb. 24, '05	W. P. Graham.	R. A. Porter.	1st and 3d Thursdays.
Univ. of Texas.....Feb. 14, '08	A. C. Scott.	B. F. Kenyon.	2d and 4th Fridays.
State Col. of Wash..Dec. 13, '07	H. V. Carpenter.	M. K. Akers.	3d Tuesday.
Washington Univ..Feb. 26, '04	C. M. Duncan.	W. E. Beatty.	2d and 4th Wednesdays.
Univ. of Wisconsin.Oct. 15, '02	O. H. Ensign.	J. W. Shuster.	Every Thursday. [4th Thursday (Public Meeting.)]
Worcester Poly. Inst. Mar. 25, '04	L. W. Hitchcock	W. D. Stearns.	Alternate Fridays.

Section and Branch Secretaries

AMES, IOWA.—ADOLPH SHANE,
Iowa State College.

ANN ARBOR, MICH.—H. F. BAXTER,
556 S. State St.

ATLANTA, GA.—G. J. YUNDT,
Southern Bell Tel. & Tel. Co.

AUSTIN, TEXAS.—B. F. KENYON,
University of Texas

BALTIMORE, MD.—CHAS. G. EDWARDS,
Electrical Commission, City Hall

BETHLEHEM, PA.—J. A. CLARKE, Jr.,
Lehigh University.

BOSTON, MASS.—A. L. PEARSON,
93 Federal St.

BOULDER, COLO.—H. S. BUCHANAN,
University of Colorado.

BOZEMAN, MONT.—J. A. THALER,
Montana Agricultural College.

CHICAGO, ILL.—J. E. SNOW,
Armour Inst. of Technology.

CHICAGO, ILL.—P. B. WOODWORTH,
Lewis Institute.

CHICAGO, ILL.—J. G. WRAY,
Chicago Telephone Co.

CINCINNATI, O.—A. C. LANIER,
University of Cincinnati.

CINCINNATI, O.—C. C. BUCHANAN,
University of Cincinnati.

CLEVELAND, O.—F. M. HIBBEN,
10207 Wilbur Avenue.

COLUMBIA, MO.—H. D. CARPENTER,
University of Missouri.

COLUMBUS, O.—F. C. CALDWELL,
Ohio State University.

COLUMBUS, O.—H. L. BACHMAN,
533 South 3d St

CORVALLIS, ORE.—E. C. WRIGHT,
Oregon Agr. College.

FAYETTEVILLE, ARK.—C. R. RHODES,
University of Arkansas.

ITHACA, N. Y.—H. H. NORRIS,
Franklin Hall, Cornell University.

LAFAYETTE, IND.—H. T. PLUMB,
Electrical Eng. Dept., Purdue University

LAWRENCE, KAN.—H. P. BRODERSON,
University of Kansas.

LINCOLN, NEB.—L. E. HURTZ,
Lincoln Tel. Co.

MADISON, WIS.—J. W. SHUSTER,
University of Wisconsin.

MANHATTAN, KAN.—W. C. LANE,
Kansas State Agr. College.

CITY OF MEXICO.—F. D. NIMS,
Mexican Light & Power Co.

MISSOULA, MONT.—S. R. INCH,
Univ. of Montana.

NORFOLK, VA.—F. W. WALTER,
National Bank of Commerce.

ORONO, MAINE,—GUSTAV WITTIG,
University of Maine.

PENN. STATE COLLEGE, PA.—C. D. PRESTON,
Penn. State College.

PHILADELPHIA, PA.—H. F. SANVILLE,
1122 North American Building.

PITTSBURG, PA.—R. A. L. SNYDER,
1332 Fulton Building

PITTSFIELD, MASS.—H. L. SMITH,
Stanley-G. I. Elec. Mfg. Co

PULLMAN, WASH.—M. K. AKERS,
State College of Washington

ST. LOUIS, MO.—C. M. DUNCAN,
Washington University.

ST. LOUIS, MO.—H. I. FINCH,
5217 Morgan Street.

ST. PAUL, MINN.—A. L. ABBOTT,
165 E. 4th St.

SAN FRANCISCO, CAL.—G. R. MURPHY,
11 Hawthorne St., San Francisco.

SCHENECTADY, N. Y—J. MASON KNOX,
General Electric Co.

SEATTLE, WASH.—GEORGE H. MOORE,
1726 Harvard Ave.

STANFORD UNIVERSITY.—A. J. GOWAN,
Leland Stanford, Jr., University.

SYRACUSE, N. Y.—R. A. PORTER,
Syracuse University.

TOLEDO, OHIO.—GEO. E. KIRK,
The Nicholas.

TORONTO, ONT.—W. G. CHACE,
551 Confederation Life Building.

URBANA, ILL.—ELLERY B. PAINE,
University of Illinois.

WASHINGTON, D. C.—PHILANDER BETTS,
Metropolitan Bank Bldg.

WORCESTER MASS.—W. D. STEARNS,
Worcester Poly. Inst.

Local Honorary Secretaries

JAMES S. FITZMAURICE,
210 George St., Sydney, N. S. W.

H. F. PARSHALL,
Salisbury House, London Wall E. C., London.

ROBERT B. OWENS,
McGill University, Montreal, P. Q.

WILLIAM B. HALE,
Cadena 10, City of Mexico.

W. G. T. GOODMAN,
Adelaide, South Australia.

ROBERT J. SCOTT,
Christ Church. New Zealand

PROCEEDINGS
OF THE
American Institute
OF
Electrical Engineers.

Published monthly at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE
GEORGE F. SEVER, Chairman
A. H. ARMSTRONG SAMUEL SHELDON

GEORGE A. WARDLAW, Editor

Subscription. United States, Mexico and Cuba, $5.00 per year.
All other countries $6.00 per year.
Single copy 50 cents.
Subscriptions must begin with January issue.

Advertisements accepted from reputable concerns at the following net rates:

Space	Less than half year per issue	Half year per issue	One year per issue
1 page	$50.00	$44.00	$40.00
½ page	30.00	25.00	22.00

Additional charges for Preferred Positions.

Changes of advertising copy should reach this office by the 10th of the month, for the issue of the following month.

Vol. XXVII October, 1908 No. 10

October Meeting

THE first meeting of the Institute in New York for the year 1908–1909 will be held in the auditorium of the Engineers' Building, 33 West Thirty-ninth street, on Friday, October 9, at 8 p.m. Messrs. Peter Junkersfeld and E. O. Schweitzer, of the Commonwealth Edison Company of Chicago, will present a paper entitled " High-Potential Underground Transmission ".

Fewer Papers

IT has been obvious for several years that continual increase in the number of papers presented at the monthly meetings of the Institute would eventually interfere with free discussion, and that some change in policy was inevitable. The Meetings and Papers Committee proposes to accept but one paper for each meeting during the present season, to be followed by prepared discussion, closing not later than ten o'clock, at which hour open discussion will be invited. While the adoption of this practice is likely to diminish the number of papers, it should raise the standard of excellence, and make it necessary for authors to arrange for dates earlier in the season. Possibly another result may be an increase in the number of original papers available for Sections meetings. A similar policy will be adopted for the annual convention, and it is hoped that the membership will appreciate the necessity of economizing in the time heretofore required for carrying out the programs, which have been growing from year to year, until the problem of properly caring for them has become serious.

Elevator Facilities

SINCE the library has been open evenings, and the number of meetings held in the Engineers' Building has increased, it has been found necessary to install an additional elevator, for which space was allowed in the designing of the structure. The contract was given out early in the summer by authority of the Board of Trustees of the United Engineering Society, and the elevator is now available.

Scientific Forestry

IN spite of the recent and extensive interest shown in the subject of forestry, there has been little known regarding practical work in this country. An opportunity will be offered at Biltmore, N. C., in November next for a thorough examination of the results of twenty years scientific forestry on the Vanderbilt property. All members interested in this work are invited to attend. Details of the proposed celebration are given on another page.

Electric Cables*

By H. W. Fisher.

The subject of electric cables, in its entirety, is so broad that several papers would be necessary to do it full justice. Much could be written about the material entering into the construction of cables, much about the manufacture of cables, and a great deal about the testing and installation of cables. A description of the different kinds of cable and the use for which they are intended would of itself be enough for one paper. In addition to all this, the subject of cable data such as would be of interest or benefit to operators or consulting engineers covers a large and only partly explored field. Under this heading may be mentioned tests to determine the eddy current losses in the conductors and lead covers of various sized cables transmitting alternating currents, variation of impedances of armored cables and of ordinary cables with and without the lead covers connected at each end, dielectric losses, current carrying capacities, etc.

Amongst recent papers dealing with cable problems may be mentioned the following:

1. "Power Losses in Dielectrics With High Voltage Alternating Currents, by Paul Humann, in the *Elektrische Bahnen U.* Betriebe, commencing August 24, 1906.

2. "The Theory of Alternating Current Transmission Cables," by C. V. Drysdale, in the *London Electrician*, commencing December 6, 1907.

3. "The Dielectric Strength of Insulating Materials and the Grading of Cables," by A. Russell, commencing the *Electrical Review*, Nov. 16, 1907. This paper was read before the Institution of Electrical Engineers of England.

It is thought best first to speak of the recent types of cables, terminals, etc., submitting for inspection samples of the same, and then take up some of the theoretical consideration showing along what lines improvements may be made to meet probable future requirements.

Telegraph cables. The telegraph companies both here and abroad are now using dry-core cables with paper insulation so as to reduce the electrostatic capacity to a minimum. Where these cables are used for the transmission of telegraph signals over long distances, twisted pairs are employed, or else the cable is made up of a number of groups of four conductors, the diagonally opposite wires of each group being used for each circuit. Telegraphic service is now being conducted over cable more than 125 miles long, and it is possible through this distance to operate quadruplex and Wheatstone instruments successfully.

Telephone cables. In the use of telephone cables, a low electrostatic capacity is desirable, indeed it is very essential where telephonic transmission has to be conducted over long distances. Telephone cables are made commercially with capacities ranging between 0.12 and 0.08 microfarads per mile. The size of conductors employed runs from No. 22 to No. 13 B. & S. gauge. Recently there has been considerable demand for the larger size wires such as No. 16, 14, and 13. Such wires are generally used for toll and long-distance service. Practically all of the Bell Telephone Company's specifications require a mutual capacity test. By this is meant the capacity between one wire of a pair and its mate, with the other wires connected to the lead cover of the cable. This capacity is about two-thirds of the capacity by the old method, which consisted in testing each wire against all the other wires grounded to the lead cover of the cable. Some of the recent requirements on No. 16 and 13 wires specify a mutual test of 0.065 microfarads per mile.

With the use of the Pupin coils for helping to neutralize the effects of capacity, it was found that telephonic disturbances due to a condition of unbalance between adjacent pairs in a telephone cable were greatly accentuated by the use of said coils. An apparatus was, therefore, designed by the Bell Telephone Company for measuring the amount of unbalance capacity between wires of adjacent pairs, and this led to a new specification which required that the average mutual capacity unbalance between adjacent pairs should not exceed 0.000025 microfarads. By exercising extreme care and special methods of manufacture the above specifications can be complied with.

---

* A paper read by Henry W. Fisher before a meeting of the Pittsburgh Section, February 5, 1908, and before the Toledo Section, February 7, 1908.

Electric light and power cables. Paper varnished cloth, and rubber are the three kinds of insulation which are mostly used in the manufacture of the above kinds of cable. Paper insulated cables are now being used commercially on circuits running as high as 22,000 volts and are giving excellent satisfaction. When there is a demand for cables to operate at higher voltages than 22,000, paper cables will no doubt be supplied, although at the present time it is difficult to predict what the ultimate maximum voltage limit will be. Refined laboratory experiments indicate great possibilities for paper insulated cables.

Paper insulated cables are made up in a great variety of forms such as single conductor, duplex, triplex, multiple, and concentric. On account of the difficulty of making joints the concentric is not used very extensively in this country. Millions of feet of three-conductor, paper-insulated cable are now working at 11,000 volts in a very successful manner. The better forms of paper cables are saturated with a soft oily compound. The insulation resistance of such cables is low but the most important consideration, dielectric strength, is high. A soft compound has to be employed so that the cables can be bent without liability to crack the paper or compound.

In a special form of cable the conductors forming the strand are laid over a lead pipe, then $\frac{4}{32}$ in. of saturated paper is applied and then a lead cover $\frac{3}{16}$ in. thick. This type of cable is designed more for power house work where conductors may have to carry an unusually large amount of current in order to save floor or wall space. The cable on exhibition consists of 500,000 cir. mils, and a comparison between it and the regular 500,000-cir. mil cable with the same thickness of insulation gave the following results:

The hole in the center lead pipe of the special cable was $\frac{9}{16}$ in. and the thickness of lead $\frac{5}{32}$ in. The outside diameter of the finished cable was $1\frac{49}{64}$ in. while that of the regular cable was $1\frac{29}{64}$ in.

The cables were laid upon a wooden floor about one foot apart and the same current passed through both of them. In the strand of both conductors was inserted a thermal couple by means of which an accurate determination of the temperature of the conductor was obtained. With a current of 600 amperes the final rise of temperature above the air was, for the regular cable, 93° fahr. and for the special cable 69° fahr. Here no attempt was made to cool the conductor of the special cable by the circulation of oil through the inner lead pipe. By doing this the cable could be operated at a much greater current carrying capacity, and if the system were large the heat of the hot oil might be used for special purposes.

Paper insulated cables should be tested for insulation resistance, and a potential test of from two to two and a half times the normal working voltage should be applied. Paper insulation, not being waterproof, must always be protected by means of a lead cover.

There are a great variety of terminals on the market for protecting the ends of cables. Two open-air terminals are of special interest. These are molded hot from plastic material that does not absorb moisture. A cable connected to one of these is perfectly protected from rain, the petticoat insulator insuring a good insulation between the conductor and lead cover. The larger one is for 11,000 volts' service and the smaller for voltages up to 2500. In a rain storm, over 35,000 volts are required to flash over from the connecter of the larger terminal to the lead cover of the cable. The method of connecting this terminal will be explained later.

During the last few years so much has been written about rubber insulation that not much time will be given to it here. Very seldom is there any call for a better compound than 40% para rubber, but there has been considerable demand for 30% para and many specifications have been devised to make the requirements of such a nature that compliance therewith necessitates the use of full 30% para and no rubber of inferior grade. If all rubber cables had to be made of 30% para, the cost would be so great that there would not be much demand for them. By the use of cheaper grades of rubber and other materials that have been found to possess valuable insulating qualities, rubber cables are made that cost much less and still make a splendid showing when tested for insulation resistance and high voltage. There is no doubt but that each of the reputable rubber-covered wire manufacturers has made and tested many different kinds of rubber compounds and thus is in position to furnish cables best suited to any particular condition and requirement.

There is less demand for rubber insulated cables on account of their greater cost over that of paper insulated cables. Rubber insulated cables must not be subjected to too great temperatures because of the possible decentralization of the copper strand due to a softening of the rubber compound. For submarine work, rubber insulated cables with steel-wire armor is generally used. Where cables are buried in the ground, two steel tapes wrapped over a bedding of jute are frequently used.

With reference to improvements that may be made in different kinds of cables, it is not likely except in very special cases that the electrostatic capacity of telephone cables will be very much reduced. To make the capacity much less would require an enormous increase in the size of the cables. Moreover, while it is a comparatively easy undertaking to enclose a large amount of air when the conductor is not insulated to a large diameter, it is a much more difficult thing to keep the same relative proportion of air when the diameter of the insulated wire is made very large. It is, of course, possible that still larger wires may be used for telephone purposes, but since the introduction of Pupin coils, there is not the same necessity of making cables with a very low capacity or large size of conductor.

Probably each manufacturer of cables has his own idea of how improvements may be made in the construction of electric light cable. When the demand arises for 40,000-volt cables, they undoubtedly will be made. The one thing that tends to retard manufacturers from taking too great risks in this direction is the fact that we do not know what will be the effect of time on different dielectrics. There is no difficulty in making cables that will withstand a 100,000-volt test in the factory, but it cannot be said with any assurance that such a cable will operate successfully for five years, at 40,000 volts.

Looking at these subjects from a theoretical standpoint, a cable of the most perfect form should have a graded insulating material. By this is meant that the capacity of the insulation next to the conductor must be highest and that near the lead cover must be lowest. If this is not done, the voltage strain on the insulation is greatest at the conductor. The theoretical laws are so well known that it is possible to calculate the voltage stress at any point of the insulation, and theoretically it should be possible to make a cable where said stress is uniform all the way from the copper to the lead. In practice this cannot be done but we can approximate the theoretical condition in some styles of cable.

There has been considerable criticism as to whether the apparently theoretical laws in regard to this matter are really correct. Some writers have boldly asserted that certain tests which they have made did not confirm theory. It is so difficult to make cables which are perfectly uniform that any attempt to prove that theory and practice agree can hardly be done by the manufacture by tests of different kinds of cable having different sizes of conductors and different thicknesses of insulation. The writer has in mind a method by which he thinks the laws of grading can be investigated and he expects to carry out experiments of this nature during the present year.

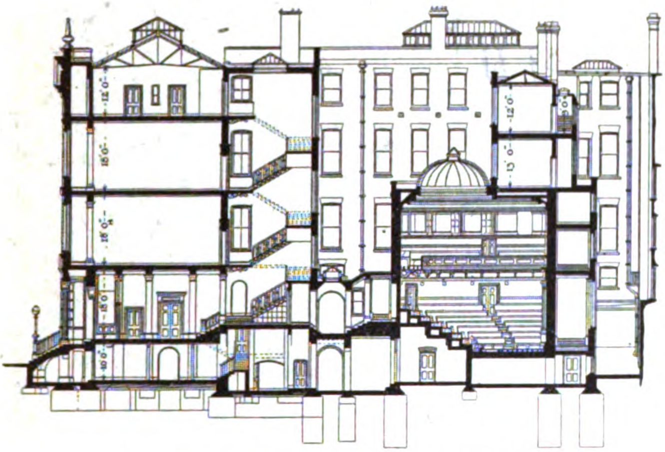


FIG. 1—Cross-section of I. E. E. Building

Mr. O'Gorman was one of the first persons to speak in a prominent way regarding the subject of grading cables. Two or three articles of his appeared in the London *Electrician* about eight or nine years ago. Mr. E. Jona presented a most able paper on the same subject at the International Electric Congress in St. Louis on Sept. 13, 1904.

The equivalent of grading can be done by employing a material of very high dielectric strength next to the conductor, and on top of this using a material of less dielectric strength, and so on gradually decreasing the dielectric strength by the use of cheaper materials until the requisite thickness of insulation is obtained. This method has also been employed by some of the cable manufacturers. Only a few of the problems that come up before the cable manufacturer are mentioned here, but as a matter of fact there are many intricate ones, the mathematics of which is extremely complicated.

New Home of the Institution of Electrical Engineers

On June 30, after considerable but chiefly favorable discussion, it was unanimously resolved by the Institution of Electrical Engineers to secure the building on the Victoria Embankment, known as the Medical Examination Hall, from the Royal College of Physicians and the Royal College of Surgeons, and make it the home of the Institution.

The building stands on the Victoria Embankment, facing one of the Embankment Gardens, and is situated between the Savoy Hotel and Waterloo Bridge. It is midway between Charing Cross and Temple stations on the District Railway, and is within a few minutes' walk of Waterloo, Charing Cross, and St. Paul's stations, and is close to the new Strand station of the underground electric railways. It is almost at the point of junction of the tramways of the north and south of London. It is reached from the Strand by Savoy street and Savoy Hill.

The building occupies nearly a square site (over 20,000 sq. ft.). It comprises three floors and a basement, and has a lecture theatre in addition to a large number of very handsome well-lighted lofty rooms. The building contains a floor space, exclusive of corridors, entrance halls, and passages, of more than 40,000 sq. ft.

The property is taken on a lease which has 76 years to run, and against which an annual sum of $1,000 will be set off for amortization. The building is handsome and commodious. For some time to come the Institution will not require all of it, but will be able to house a few kindred societies, after the manner of the Engineers' Building in New York.

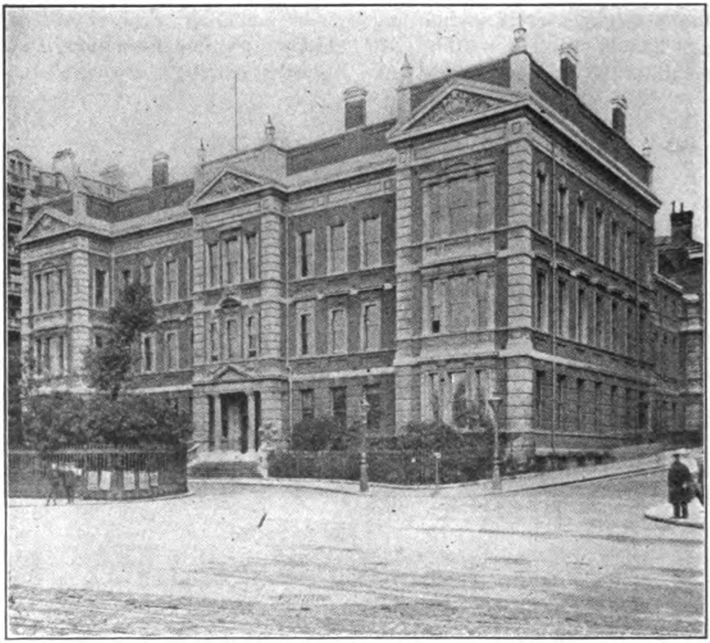


Fig. 2—Elevation of I. E. E. Building

The I. E. E. and its Local Sections*

" Before I sit down I should like, with your permission, to refer to two events of the past year which are, I think, of some importance. In the first place, with this year a somewhat novel procedure as to dealing with papers to be read before the Institution is to be inaugurated. Hitherto, the Local Sections of the Institution have acted without any very close coöperation amongst themselves, or without any very well organized endeavor to work together for the whole benefit of the Institution. That matter has been under careful thought and consideration during the past year, with the result that it appeared that our plan of procedure in dealing with papers might be modified so as to strengthen the

---

* Excerpt from remarks of Dr. R. T. Glazebrook retiring President of Institution of Electrical Engineers, November 14, 1907.

Institution, and obtain for each member more of the value of the work of individual members. In the past, papers have been read at the Local Sections and then have been sent up to London, where they have come before the Papers Committee and the Council, and after discussion it has been decided whether or not they were to appear in the Journal. By the new arrangements that procedure is to be altered. The constitution of the Papers Committee has been changed, and it now consists of representatives of all the Local Sections as well as of representatives of the Council. Every paper which is to be read before the Institution or before one of the meetings of the Local Sections will come before that Committee before being read. The Committee will then make recommendations to the Council as to which of all these papers should be selected for reading and discussion at a general meeting in London. Those papers and all the other papers will be open to all the Local Sections for inclusion in their programmes, and an endeavor will be made to read them in the various centres as nearly as possible at the same time as they are read in London, so that the discussion of them will take place as nearly as possible simultaneously. By this means it will be possible to focus round any point of real interest or novelty all the talent of the members of the Institution, and it is hoped that in that way our work will be strengthened, that it will be made more useful. I am glad to recognize the way in which the Local Sections are coming forward and coöperating with the Council in that work. You will hear a little later in the evening the list of papers that is passed for the present Session, and then you will feel, I am sure, that this new school has begun under extremely good auspices, and if likely to lead to results of very real value."

Evening Courses at Columbia

Columbia University will offer at night during the year 1908–09 twenty evening courses especially adapted to the needs of technical and professional workers. This includes work in applied mechanics, applied physics, architecture, electricity, fine arts, industrial chemistry, mathematics, and surveying and structures. The work begins on October 26, and continues for twenty-five weeks. A full description of the courses is contained in the announcement of extension teaching, which may be obtained on application to the director of extension teaching, Columbia University, New York City.

October Meeting A.S.M.E.

The season of professional meetings of The American Society of Mechanical Engineers will be opened on Tuesday evening, October 13 by a meeting of the gas power section in the Engineers' Building at 33 West 39th street, New York. Mr. H. L. Doherty, chairman of the meetings committee of the section, will present for discussion a report outlining plans for future work; there will also be a discussion of standards to be used in gas power work. Two papers will be read, one by E. A. Harvey on gas producer plants, with data upon costs, performance, etc.; and one by N. T. Harrington giving the results of tests to determine the loss of fuel weight in a freshly charged producer, due to increase of ash contents in the fuel bed. The first paper will be illustrated by lantern slides, showing actual plants and plans for the arrangement of apparatus.

Forestry at Biltmore

The forestry department of the Biltmore Estate propose celebrating the twentieth anniversary of forestry at Biltmore together with the tenth anniversary of the Biltmore Forest School, on November 26, 27, and 28. They extend to professional engineers and others interested a cordial invitation to attend the meeting.

Dr. C. A. Schenck, director, announces as a tentative program the following:

Thursday, November 26, Excursion over the Biltmore Estate, leaving Biltmore Village in carriages at 9:30 a.m. Inspection of the forest plantations of numerous hard and soft woods made between the years 1889 and 1905. Study of planting operations in actual progress. The director will explain the situation and purposes in view both from a sylviculture and financial standpoint. In the evening dinner at the Battery Park hotel.

Friday, November 27, Visit to Biltmore herbarium. Biltmore nurseries, inspection of the agricultural department of the estate, and study of seed regeneration of yellow poplar in compartments 102 and 104. In the evening, 'possum hunt on the estate with barbecue.

Saturday, November 28, Excursion by train to Pisgah forest, thence in carriages to the mountain forests; study of logging operations, and of second growth obtained in primeval forests logged conservatively in 1895. Lunch in the camps. Fishing and shooting in the afternoon. Pedestrians may ascend Mt. Pisgah (nearly 6,000 ft.) at sunset, spending the night at the hunting lodge.

Young as it may seem, forestry at Biltmore, in the woods and in the school, is the oldest of its kind on the American soil. There is not a better opportunity in the United States to study practical forestry than at Biltmore; side by side with primeval forests, whose beginning antedates the discovery of America, are to be seen embryo-forests of 1908. Especially of absorbing interest to the engineer must be the results of afforestation on 2500 acres of fields abandoned by the farmer.

Apart from transportation and hotel bills the only expense connected with the occasion will be a fee of $10 per capita to defray the sundry extraordinary expenses incidental to a gathering of the kind.

Dr. C. A. Schenck, and Mr. C. E. Waddell, Biltmore, N. C., will be pleased to assist in securing accommodations and rates for intending visitors.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before November 1, 1908.

7812 Oppenheimer, Baltimore, Md.
7813 Bass, Joseph E., Los Angeles, Cal.
7814 Beckwith, J. W., Newport, Wash.
7815 Bell, Edwin A., Stroudsburg, Pa.
7816 Bollschweiler, C. F., Los Angeles.
7817 Calangis, Arthur A., N. Y. City.
7818 Cannon, Fred K., Chicago, Ill.
7819 Cisneros, Anibal, Ithaca, N. Y.
7820 Cook, Edgar W., Los Angeles, Cal.
7821 Dyer, Isaac T., Los Angeles, Cal.
7822 Edwards, Joseph P., Chico, Cal.
7823 Feig, Paul Roy, New York City.
7824 Fisher, Allen H., Zamora, Michoacan, Mexico.
7825 Hatch, Frank S., Woods Cross, Utah.
7826 Herbert, George S., Celaya, Mex.
7827 Hyde, Edw. P., Washington, D. C.
7828 Jackson, J. G., Bensonhurst, L. I.
7829 Judson, C. B., Los Angeles, Cal.
7830 Kerns, R. W., Anaconda, Mont.
7831 Lee, Harold H., Sherman, Cal.
7832 Landsborough, T. R., Tonopah, Nev.
7833 Mackness, C. F., London, Eng.
7834 Mann, R. B., Nogales, Arizona.
7835 Meinig, R. E. A., New York City.
7836 Plowden, J. O., Los Angeles, Cal.
7837 Richmond, Carl A., Chicago, Ill.
7838 Seymour, J. F. Jr., Los Angeles.
7839 Troy, M. O., Schenectady, N. Y.
7840 Ward, Henry J., Chicago, Ill.
7841 Widmer, Henry, New Orleans, La.
7842 Wolff, Mark Arthur, Chili, S. A.
7843 Yeager, L. B., Los. Angeles, Cal.
7844 Gilman, Wm. F., Cristibal, C. Z.
7845 Cumming, F. J., Edmonton, Alta.,
7846 Weber, T. J., Grand Rapids, Mich.
7847 Acheson, A. R., Syracuse, N. Y.
7848 Collbohm, Max H., Madison, Wis.

7849 Goldback, M. G., Norfolk, Va.
7850 Mackenzie, H. A., Kashmir, India.
7851 Tessier, E. L., Richmond, Va.
7852 Vance, Champ. S., Los Angeles, Cal.
7853 Riley, G. A., Los Angeles, Cal.
7854 Perry, J. F., Los Angeles, Cal.
7855 Carter, C. H., Los Angeles, Cal.
7856 Taylor, A. A. W., N. Sydney, N. S. W.
7857 Roake, Chester H., Chico, Cal.
7858 Lowell, H. G., East Templeton, Mass.
7859 Harvey, R. H., Bahia, Brazil.
7860 Hobson, H. E., Dallas, Texas.
7861 Phinney, Edw. A., Ouray, Col.
7862 Trumbo, E. G., East Las Vegas, N M.
7863 Farmer, F. H., Hamilton, Ont.
7864 Millar, T. R., Brockport, N. Y.
7865 Lubbert, G. L., San Francisco, Cal
7866 Seafler, C. A., Christchurch, N. Z.
7867 Abbott, W. H., Cleveland, Ohio.
7868 Eastwood, H. W., Cleveland, O.
7869 Burns, A. E., Portland, Oregon.
7870 Bowker, Wm. R., Los Angeles, Cal
7871 Finkle, F. C., Los Angeles, Cal.
7872 Kimura, Komakichi, Osaka, Japan
7873 Van Deventer, H. R., Sumter, S.C.
7874 Barrow, C. J., Schenectady, N. Y.
7875 Boisen, L. N., Grand Rapids, Mich
7876 Clark R. J., Leadville, Colorado.
7877 Hattersley, H. A., Ft. Wayne, Ind.
7878 Manahan, F. T., McAlester, Okla.
7879 Runge, Walter, Newark, N. J.
7880 Eoff, B. M., Schenectady, N. Y.
7881 Frank, Dr. Karl Georg, N. Y. City.
7882 Richter, Henry, Chicago, Ill.
Total, 71.

Sections and Branches

PITTSBURG SECTION.

The first meeting of the Pittsburg Section for the year 1908–1909 was held in the lecture hall of the Carnegie Institute on September 9, 1908. Besides the reading of the papers, the following officers were elected for the ensuing year:

Chairman, Mr. W. Edgar Reed.
Secretary, Mr. B. P. Rowe.
Executive Committee,
  Mr. C. B. Auel,
  Mr. B. Rutherfoord,
  Mr. F. Uhlenhaut, Jr.,
  Mr. C. W. Davis,
  Mr. E. B. Tuttle,
  Mr. Ludwig Hommel.

Mr. F. D. Newbury abstracted J. L. Woodbridge's paper on "The Application of Storage-Batteries to the Regulation of Alternating-Current Systems." He explained how batteries are used in connection with synchronous converters having two-part split-pole pieces and also converters having three-part pole pieces.

Mr. R. L. Flanders read a paper on the "Relay Type of Load Regulators for Storage-Battery Systems." He showed by diagrams how happily a relay can be used together with a battery to regulate the supply of alternating current through a converter to produce a satisfactory supply of direct current.

Mr. P. M. Lincoln said that most electrical engineers are under the impression that the ratio of the direct current to the alternating current in a synchronous converter is fixed, for two-phase being 1 to 0.7 and for three-phase 1 to 0.6. These ratios do not hold exactly, and it has been known that by trimming the pole pieces and giving the proper back charge the ratios could be modified. Mr. Woodbridge has suggested changing the field form in order to change the alternating current and direct current ratio. The two-part pole piece converter has the advantage of combining the functions of a converter and regulator. The disadvantages are that it will probably be more expensive, have a distorted wave-form, the power-factor cannot be made unity, conditions are favorable for resonance with large cable systems, and also favorable for hunting.

Mr. J. L. Davis discussed Mr. Fessenden's paper on "Wireless Telephony." He explained how the energy begins to flow out into space from the antenna harp when the frequency becomes 85,000 and from that on to 100,000 the energy radiated increases from 0% to nearly 100%. He also explained the design of a high-frequency generator, the arrangement of Poulsen's arc, and the marginal method of tuning invented by Fessenden.

Mr. E. B. Tuttle spoke of the method of relaying telephone messages from wire lines to wireless transmitters and vice versa.

In the discussion, Mr. S. P. Grace, spoke of the progress made in telephony. He started with the first form of telephone, that of iron rods driven into the ground outside of forts to indicate to the defenders any attempt of an enemy to tunnel into the fort. He showed what rapid progress had been made in the art. He referred to some early letters on the invention of the telephone written by Mr. T. A. Edison to Mr. T. B. A. David.

TORONTO SECTION

The Toronto Section of the American Institute of Electrical Engineers opened their fall course of meetings in the form of an excursion to Niagara Falls, Ontario, Saturday, Sept. 19, 1908. Over twenty members and their friends joined the party. At Niagara Falls the delegation was welcomed and many courtesies were offered by the superintendents of the three Canadian Power companies.

Visits were paid in the morning to the generating stations of the Electric Development Company of Ontario and to the transformer stations of the Electrical Development Company and the Canadian Niagara Power Company. After luncheon at the Clifton Hotel, the party proceeded to the generating stations of the Canadian Niagara Power Company and the Ontario Power Company.

Members of the party remarked upon the very rapid growth of the power load delivered by these three generating stations and were also pleased that a large share of this load is going to points in Ontario, particularly Toronto and Welland.

The members of the Section took advantage of the gathering to present to the retiring secretary, W. G. Chace, of a handsome club bag in recognition of his interest in the work of the Section throughout the past two years. Mr. Chace having severed his connection with the executive of the Section owing to his approaching departure for Winnipeg.

Personal

MR. A. S. HATCH, of Detroit, Mich., has purchased the electric lighting plant at Burnside, Ky., which he intends to remodel, using a water power near by.

MR. A. C. BABSON has removed from Seattle, Washington, and purchased a property at Central Point, Oregon, where he will reside for the present for the benefit of his health.

MR. A. G. POTTS has left the Union Railway Supply Company, of Philadelphia, and is now in the operating department of the Denver & Interurban Railroad, at Denver, Colo.

MR. CHAS. E. ANDERSON is now in the inspection department of the Western Electric Company, New York City, having left the American Electrical Works, of Providence, R. I.

MR. EDWARD Y. PORTER, formerly with the Moore Electrical Company, of Newark, N. J., has engaged in illuminating engineering work in Los Angeles, with an office at 702 S.Spring street.

MR. LLOYD L. SMITH, formerly with D. C. & W. B. Jackson, Chicago, is now chief engineer and general manager of the Beatty Milling, Mining and Reduction Company, Beatty, Nevada.

MR. H. J. S. HEATHER, after a tour of inspection of electrical plants in Europe, is returning to Africa to resume his duties as electrical engineer with H. Eckstein & Company, of Johannesburg.

MR. WALTER H. BAUER is now connected with the Philadelphia office of the Fort Wayne Electric Works. He was formerly in the motor sales department of the same company, at Fort Wayne.

Mr. S. E. Gates, who for the last three years has been in various departments of the Schenectady works of the General Electric Company, has been transferred to the company's Portland, Oregon, office, where he will take up commercial work.

Mr. Edw. J. K. Mason has been appointed professor of electrical engineering and physics at the University of Pittsburgh. At the time of his appointment Mr. Mason was in charge of the testing laboratory of W. & L. E. Gurley, Troy, N. Y.

Mr. R. H. Elliott, who has been connected with the transformer engineering department of the General Electric Company at Schenectady, has been transferred to the Pittsfield, Mass. works, to which place all transformer work is being moved.

Mr. A. C. Lasher, until recently with the erecting department of the Atlanta, Ga. office of the Westinghouse Electric & Manufacturing Company, is now chief electrician at the new shops of the Central of Georgia Railroad Company, at Macon, Ga.

Mr. W. M. Hoen has just completed two years work as electrical engineer with Cia Minera Las Dos Estrellas, in state of Michoacan, Mexico, and has assumed charge of the El Oro Mining & Railway Company, and the Mexican mines of El Oro, Mexico.

Mr. E. H. Bru having completed the electrical installation for the Real del Monte & Pachuca Company, Pachuca, Mexico, is enjoying an outing in the mountains, near San Francisco. He expects to resume the practise of his profession in October.

Mr. A. W. Copley, who has been making special investigations on the N. Y. N. H. & H. R.R. for the Westinghouse Electric and Manufacturing Company, has returned to Pittsburgh, where he will resume work in the engineering department of that company.

Mr. Malcolm MacLaren, head of the railway project division of the engineering department of the Westinghouse Electric & Manufacturing Company at Pittsburgh, has accepted the position of Professor of electrical engineering at Princeton University.

Mr. Frank W. Graham, formerly superintendent of construction of the Jamestown Exposition, has associated himself with the Chicago, Milwaukee Road & Realty Company, as assistant manager of electrical construction with offices at 134 Monroe Street, Chicago.

Mr. H. C. Eddy, who in January 1907 became superintendent of the electrical department of the District of Columbia, has been appointed executive officer and secretary of the District Electric Railway Commission, with headquarters at 806 Westory Building, Washington, D. C.

Mr. W. W. Cole, late general manager of the Elmira Water, Light and Railroad Company, has become associated with them as general manager of their public utilities department, and as expert on examinations and reports of water power, gas, and electric properties.

Mr. W. H. MacGregor, for the past eight years senior salesman in the supply department of the Westinghouse Electric & Manufacturing Company, at their New York office, has accepted the position of manager of the New York office of the Dictaphone Company of America.

Mr. H. I. Emanuel, who has had charge of the installation of the electric locomotives at the St. Clair tunnel, between Port Huron, Michigan, and Sarnia, Ontario, has completed the work, and left for his home at Asheville,

N. C. to take a vacation before taking up further work.

MR. O. C. RAUSCHENBERG has been transferred to Albany, Ga., as district plant chief for the Southern Bell Telephone and Telegraph Company, and will have charge of all plant details in southern Georgia. He was cable foreman for the same company, in Birmingham, Ala., prior to his transfer.

MR. SAMUEL R. KIMBLE, Master Electrician, C. A. C., U. S. Army, for the last five years in charge of the electrical installation at the sea-coast fortifications, Artillery District of the Delaware, has been transferred to the Artillery District of the Narragansett Bay, where he will have charge of the same department.

MR. ROBERT HOWES, until recently construction superintendent for the L. N. Farnum Company, of Boston, has opened an office in the American Bank Building, Seattle, Washington, where he is doing a general consulting and engineering business, making a specialty of hydroelectric work in the Northwest and Alaska.

MR. DAVID D. GIBSON, JR., has resigned his position as sub-station operator with the Capital Traction Company, of Washington, D. C., to accept an appointment in the U. S. Civil Service, as manual training teacher of steam and electrical engineering in the Indian Service, and is stationed at the Mescalero Agency, New Mexico.

DR. NEVIL MONROE HOPKINS, at present an assistant professor in the George Washington University, Washington, D. C., and chief electrical engineer for the United States Navy Department in the consolidation of navy yard power plants, has written a complete detective novel entitled " The Investigation at Holman Square ", which is the leading feature of the September Lippincott's.

Books Received

The following volumes have been received and placed in the Library of the Idstitute:

STANDARD POLYPHASE APPARATUS AND SYSTEMS. By Maurice A. Oudin, M.S., Mem. A.I.E.E. With 207 photo-reproductions, diagrams, and 21 tables. Fifth edition, revised and enlarged. 369 pages. New York: D. Van Nostrand Company. London: Sampson, Low, Marston & Company, Ltd. 1907. Price, $3.00 net.

CONTENTS.—Chapter I.—Definitions of Alternating-Current Terms. II.—Generators. III.—Generators (concluded). IV.—Induction Motors. V.—Induction Motors (concluded). VI.—Synchronous Motors. VII.—Transformers. VIII.—Rotary Converters. IX. — Motor-Generators, Frequency Changers, and Other Converting Apparatus. X. — Switchboards and Station Equipment. XI.—Lightning Protection and Line Construction. XII.—Two-phase System. XIII.—Three-Phase System. XIV.—Choice of Frequency. XV.—Relative Weights of Copper for Various Systems. XVI.—Calculation of Transmission Lines. Index.

ARRANGEMENT OF ELECTROLYTIC LABORATORIES WITH SPECIAL REFERENCE TO THE REQUIREMENTS OF METALLURGICAL PRACTICE. By H. Nissenson. Authorized translation by Joseph W. Richards, A.C., M.S., Ph.D. 81 pages. Illustrated. Easton, Pa.: The Chemical Publishing Company. 1905. Price, $125..

CONTENTS.—Part I.—Introduction. Purpose and Value of Electrolysis. Fundamental Ideas. Fundamental Laws of Electro-Technology. Calculation of Conductors. Components of an Electrolytic Equipment. Part II.—Description and Equipment of Electrolytic Laboratories. Aachen. Breslau. Clausthal. Darmstadt. Freilberg, Saxony. Giessen. Hoboken near Antwerp (Desilverizing Works). Konigsberg. Leoben. Central Laboratory of Dumont Brothers at Luttich. Munich. University of Pennsylvania. Stolberg. Central Laboratory of the Stolberg Company. The Electrochemical Laboratory of the Massachusetts Institute of Technology. By Prof. H. M. Goodwin. Laboratory of Applied Electro-chemistry, University of Wisconsin. By. Prof Charles F. Burgess. Lehigh University. By Prof. T. W. Richards.

Officers and Board of Directors, 1908-1909

PRESIDENT

LOUIS A. FERGUSON, Chicago, Ill.

JUNIOR PAST-PRESIDENTS.

SAMUEL SHELDON, Brooklyn, N. Y.
HENRY GORDON STOTT, New York, N. Y.

VICE-PRESIDENTS

JAMES G. WHITE, New York, N. Y.
JOHN J. CARTY, New York, N. Y.
W. C. L. EGLIN, Philadelphia, Pa.

CUMMINGS C. CHESNEY, Pittsfield, Mass.
BANCROFT GHERARDI, New York, N. Y.
CALVERT TOWNLEY, New Haven, Conn.

MANAGERS

A. M. SCHOEN, Atlanta, Ga.
PAUL M. LINCOLN, Pittsburgh, Pa.
PAUL SPENCER, Philadelphia, Pa.
WILLIAM S. MURRAY, New Haven, Conn.

MORGAN BROOKS, Urbana, Ill.
HAROLD W. BUCK, New York, N. Y.
PERCY H. THOMAS, Montclair, N. J.
BENJAMIN G. LAMME, Pittsburgh, Pa.

DAVID B. RUSHMORE, Schenectady, N. Y.
W. G. CARLTON, New York N. Y.
CHARLES W. STONE, Schenectady, N. Y.
H. E. CLIFFORD, Boston, Mass.

TREASURER

GEORGE A. HAMILTON, New York, N. Y.

SECRETARY

RALPH W. POPE, New York, N. Y.

PAST-PRESIDENTS

T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
ALEX. GRAHAM BELL, 1891-2.
FRANK J. SPRAGUE, 1892-3.
EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS B. CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1901.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, JR., 1904.5.
SCHUYLER S. WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY GORDON STOTT, 1907-8.

ASSISTANT SECRETARY

FREDERICK L. HUTCHINSON,
33 West 39th Street, New York, N. Y.

GENERAL COUNSEL

PARKER and AARON,
52 Broadway, New York N. Y.

Standing Committees

EXECUTIVE COMMITTEE

LOUIS A. FERGUSON, Chairman.
139 Adams St., Chicago, Ill.
RALPH W. POPE, New York.
GEORGE A. HAMILTON, New York.
CALVERT TOWNLEY, New Haven, Conn.
C. C. CHESNEY, Pittsfield, Mass.
WM. C. L. EGLIN, Philadelphia, Pa.
JOHN J. CARTY, New York.

FINANCE COMMITTEE

CALVERT TOWNLEY, Chairman.
Consolidated Railway Co., New Haven, Conn
HAROLD W. BUCK New York.
BANCROFT GHERARDI, New York.

LIBRARY COMMITTEE

EDWARD CALDWELL, Chairman.
239 W. 39th St., New York.
MAX LOEWENTHAL, New York.
PHILIP TORCHIO, New York.
H. E. CLIFFORD, Boston, Mass.
W. G. CARLTON, New York.

MEETINGS AND PAPERS COMMITTEE

A. H. ARMSTRONG, Chairman.
Schenectady, N. Y.
C. E. SKINNER, Pittsburgh, Pa.
RALPH D. MERSHON, New York.
H. H. NORRIS, Ithaca, N. Y.
BION J. ARNOLD, Chicago, Ill.
JOHN J. CARTY, New York.

EDITING COMMITTEE

GEORGE F. SEVER, Chairman.
Columbia University, New York
A. H. ARMSTRONG, Schenectady, N. Y.
SAMUEL SHELDON, Brooklyn, N. Y.

BOARD OF EXAMINERS

HAROLD W. BUCK, Chairman.
49 Wall St., New York.
H. H. BARNES, JR., New York.
MAURICE COSTER, New York.
D. C. JACKSON, Boston, Mass.
W. G. CARLTON, New York.

STANDARDS COMMITTEE

SAMUEL SHELDON, Chairman.
Polytechnic Institute, Brooklyn, N. Y.
S. W. STRATTON, Washington, D. C.
C. P. STEINMETZ, Schenectady, N. Y.
CLAYTON H. SHARP, New York.
J. W. LIEB, JR., New York.
B. A. BEHREND, Milwaukee, Wis.
A. E. KENNELLY, Boston, Mass.
CHARLES F. SCOTT, Pittsburgh, Pa.
GANO DUNN, Ampere, N. J.

CODE COMMITTEE

F. A. C. PERRINE, Chairman.
60 Wall St., New York.
W. H. BLOOD, JR., Boston, Mass.
H. B. GEAR, Chicago, Ill.
ARTHUR WILLIAMS, St. Louis, Mo.
WASHINGTON DEVEREUX, Phila., Pa.
C. W. STONE, Schenectady, N. Y.
H. S. WARREN, New York.
JOSEPH C. FORSYTH, New York.
FARLEY OSGOOD, Newark, N. J.

LAW COMMITTEE

H. G. STOTT, Chairman.
600 West 59th St., New York.
SAMUEL SHELDON, Brooklyn, N. Y.
J. W. LIEB, JR., New York.
A. E. KENNELLY, Boston, Mass.
CHARLES F. SCOTT, Pittsburgh, Pa.

SECTIONS COMMITTEE

PAUL SPENCER, Chairman.
Broad and Arch Sts., Philadelphia, Pa
H. H. NORRIS, Ithaca, N. Y.
D. B. RUSHMORE, Schenectady, N. Y.
PAUL M. LINCOLN, Pittsburgh, Pa.
H. R. KING, Chicago, Ill.

Special Committees

RAILWAY COMMITTEE

(Sub-com. of Meetings and Papers Committee.)

BION J. ARNOLD, Chairman.
181 La Salle St., Chicago, Ill.
GEORGE GIBBS, New York.
N. W. STORER, Pittsburgh, Pa.
H. ST. CLAIR PUTNAM, New York.
E. H. ANDERSON, Schenectady, N. Y.

EDUCATIONAL COMMITTEE

(Sub-com. of Meetings and Papers Committee.)

HENRY H. NORRIS, Chairman.
Cornell University, Ithaca, N. Y
CHARLES F. SCOTT, Pittsburgh, Pa.
C. O. MAILLOUX, New York.
GANO DUNN, Ampere, N. J.
H. E. CLIFFORD, Boston, Mass.
CHARLES P. STEINMETZ, Schenectady, N.Y

HIGH-TENSION TRANSMISSION COMMITTEE

(Sub com. of Meetings and Papers Committee.)

RALPH D. MERSHON, Chairman.
60 Wall St., New York.
PAUL M. LINCOLN, Pittsburgh, Pa.
W. S. MOODY, Schenectady, N. Y.
C. C. CHESNEY, Pittsfield, Mass.
W. N. RYERSON, Niagara Falls, N. Y.

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES

H. G. STOTT, Chairman.
600 West 59th St., New York.
CHARLES H. PORTER, Boston, Mass.
W. H. BLOOD, JR., Boston, Mass.
W. L. ABBOTT, Chicago, Ill.
JOHN H. FINNEY, Atlanta, Ga.
P. G. GOSSLER, New York.
F. A. C. PERRINE, New York.

EDISON MEDAL COMMITTEE.

CHARLES L. CLARKE, Chairman.
120 Broadway, New York City.
COMFORT A. ADAMS,
WILLIAM S. BARSTOW,
WILLIAM HAND BROWNE, JR.,
HENRY L. DOHERTY
GANO DUNN,
GEORGE A. HAMILTON,
JOHN W. HOWELL,
D. C. JACKSON,
CHARLES E. LUCKE,
THOMAS C. MARTIN.
SAMUEL REBER,
CHARLES F. SCOTT
HENRY G. STOTT,
CHARLES A. TERRY,

JOHN FRITZ MEDAL REPRESENTATIVES.

HENRY G. STOTT,
SAMUEL SHELDON,
SCHUYLER S WHEELER,
JOHN W. LIEB, JR.

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

United States National Committee.

ELIHU THOMSON, President, Lynn, Mass.
CHARLES F. SCOTT, 1st Vice-president.
SAMUEL SHELDON, 2d Vice-president.
ARTHUR E. KENNELLY, Secretary.
BION J. ARNOLD.
B. A. BEHREND.
ARTHUR W. BERRESFORD.
JOHN J. CARTY.
W. C. L. EGLIN.
CARL HERING.
JOHN W. HOWELL,
DUGALD C. JACKSON,
FRANCIS W. JONES,
BENJAMIN G. LAMME.
W. A. LAYMAN,
JOHN W. LIEB, JR.,
CLAYTON H. SHARP,
CHARLES P. STEINMETZ,
LEWIS B. STILLWELL,
HENRY G. STOTT,
SAMUEL W. STRATTON,

Local Honorary Secretaries

JAMES S. FITZMAURICE,
210 George St., Sydney, N. S. W.

H. F. PARSHALL,
Salisbury House, London Wall E. C., London.

ROBERT B. OWENS,
McGill University, Montreal, P. Q.

WILLIAM B. HALE,
Cadena 10, City of Mexico.

W. G. T. GOODMAN,
Adelaide, South Australia.

ROBERT J. SCOTT,
Christ Church, New Zealand.

Sections and Branches—Directory.

Sections	Organization authorized by Board of Directors	Chairman	Secretary
Atlanta	Jan. 19, '04	J. H. Finney	G. J. Yundt, Southern Bell Tel. Co., Atlanta, Ga.
Baltimore	Dec. 16, '04	J. B. Whitehead	C. G. Edwards, City Hall, Baltimore, Md.
Boston	Feb. 13, '03	A. E. Kennelly	A. L. Pearson, 93 Federal St., Boston, Mass.
Chicago	1893	H. R. King	J. G. Wray, 203 Washington St., Chicago, Ill.
Cincinnati	Dec. 17, '02	A. G. Wessling	
Cleveland	Sept. 27, '07	Henry B. Dates	F. M. Hibben, 1549 Winton Ave., Cleveland, O.
Columbus	Dec. 20, '03	R. J. Feather	H. L. Bachman, 1070 E. Fulton St., Columbus, O.
Fort Wayne	Aug. 14, '08	E. A. Wagner	M. J. Kehoe, 1318 McLellan St., Ft. Wayne, Ind.
Ithaca	Oct. 15, '02	E. L. Nichols	H. H. Norris, Cornell Univ., Ithaca, N. Y.
Los Angeles	May 19, '08	C. W. Koiner	J. E. MacDonald, 444 P. E. Bldg., Los Angeles, Cal.
Mexico	Dec. 13, '07	R. F. Hayward	F. D. Nims, Mex. Lt. & Pr. Co., Mexico, Mex.
Minnesota	Apr. 7, '02	E. H. Scofield	A. L. Abbott, 185 E. 4th St., St. Paul, Minn.
Norfolk	Mar. 13, '08	D. G. Stanbrough	R. R. Grant, P. O. Box 254, Norfolk, Va.
Philadelphia	Feb. 18, '03;	Paul Spencer	H. F. Sanville, 1708 Swansom St., Phila., Pa.
Pittsburg	Oct. 13, '02	W. Edgar Reed	B. P. Rowe, 911 Ramsey Ave., Wilkinsburg, Pa.
Pittsfield	Mar. 25, '04	W. A. Hall	H. W. Tobey, General Electric Co., Pittsfield, Mass.
San Francisco	Dec. 23, '04	A. M. Hunt.	G. R. Murphy, 2699 Union St., San Francisco, Cal.
Schenectady	Jan. 26, '03	D. B. Rushmore	J. M. Knox, 1205 Union St., Schenectady, N. Y.
Seattle	Jan. 19, '04	J. H. Harisberger	Geo. H. Moore, 816 Terry Ave., Seattle, Wash.
St. Louis	Jan. 14, '03	A. S. Langsdorf	H. I. Finch, 5228 Kensington Ave., St. Louis, Mo,
Toledo	June 3, '07	C. R. McKay	Geo. E. Kirk, 1614 The Nichols, Toledo, O.
Toronto	Sept. 30, '03	W. A. Bucke	W. G. Chace, 124 Confed. Life Bldg., Toronto, Can.
Urbana	Nov. 25, '02	J. M. Bryant	E. B. Paine, Univ. of Illinois, Urbana, Ill.
Washington, D. C.	Apr. 9, '03	Philander Betts	H. C. Eddy, 806 Westory Building, Washington, D. C.

Sections and Branches—Directory.

Branches	Organized	Chairman	Secretary
Arkansas, Univ. of....	Mar. 25, '04	M. F. Thompson	C. R. Rhodes, Univ. of Ark., Fayetteville, Ark.
Armour Institute......	Feb. 26, '04	T. W. Simpson	J. E. Snow, Armour Inst. Tech., Chicago, Ill.
Cincinnati. Univ. of...	Apr. 10, '08	C. R. Wylie	C. C. Buchanan, Univ. of Cincinnati, O.
Colorado, Univ. of.....	Dec. 16, '04	H. H. Watters	L. D. Jones, Univ. of Colorado, Boulder, Colo.
Iowa State College....	Apr. 15, '03	F. A. Fish	Adolph Shane, Iowa State College, Ames, Ia.
Kansas State Agr. Col..	Jan. 10, '08	W. L. Enfield	W. C. Lane, Kan. State Agr. Col., Manhattan, Kan.
Kansas, Univ. of......	Mar. 18, '08	Martin E. Rice	H. P. Broderson, Univ. of Kansas, Lawrence, Kan.
Lehigh University.....	Oct. 15, '02	H. O. Stephens	J. A. Clarke, Jr., Lehigh Univ., Bethlehem, Pa.
Lewis Institute........	Nov. 8, '07	W. H. Hayes	P. B. Woodworth, Lewis Institute, Chicago, Ill.
Maine, Univ. of.......	Dec. 26, '06		Gustav Wittig, Univ. of Maine, Orono, Me.
Michigan, Univ. of....	Mar. 25, '04	C. M. Davis	H. F. Baxter, 556 S. State St., Ann Arbor, Mich.
Missouri, Univ. of.....	Jan. 10, '03	H. B. Shaw	H. D. Carpenter, Univ. of Missouri, Columbia, Mo.
Montana Univ. of.....	May 21, '07	Robert Sibley	
Montana Agr. Col.....	May 21, '07	B. S. Hind	J. A. Thaler, Montana Agr. Col., Bozeman, Mont.
Nebraska, Univ. of....	Apr. 10, '08	Geo. H. Morse	L. E. Hurtz, Lincoln Tel. Co., Lincoln, Neb.
Ohio State Univ......	Dec. 20, '02	F. W. Funk	F. C. Caldwell, Ohio State Univ., Columbus O.
Oregon State Agr. Col..	Mar. 24, '08	E. V. Hawley	E. C. Wiggen, Oregon St. Agr. Col., Corvallis, Ore.
Penn. State College....	Dec. 20, '02	D. R. Simpson	C. D. Preston, Penn. State College, Pa.
Purdue Univ..........	Jan. 26, '03	J. W. Esterline	H. T. Plumb, Purdue Univ., Lafayette, Ind.
Stanford Univ........	Dec. 13, '07	W. C. North	A. J. Gowan, Stanford Univ., California.
Syracuse Univ........	Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse Univ., Syracuse, N. Y.
Texas, Univ. of.......	Feb. 14, '08	A. C. Scott	B. E. Kenyon, Univ. of Texas, Austin, Tex.
Wash. State Col. of...	Dec. 13, '07	H. V. Carpenter	M. K. Akers, State Col. of Wash., Pullman, Wash.
Washington Univ.....	Feb. 26, '04	C. M. Duncan	
Wisconsin, Univ. of...	Oct. 15, '02	O. H. Ensign	J. W. Shuster, Univ. of Wisconsin, Madison, Wis.
Worcester Poly. Inst..	Mar. 25, '04	F. A. Spencer	W. D. Stearns Worcester Poly. Inst., Worcester, Mass.

PROCEEDINGS
OF THE
American Institute
OF
Electrical Engineers.

Published monthly at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE
GEORGE F. SEVER, Chairman
A. H. ARMSTRONG SAMUEL SHELDON

GEORGE A. WARDLAW, Editor

Subscription. United States, Mexico and Cuba, $5.00 per year.
All other countries $6.00 per year.
Single copy 50 cents.
Subscriptions must begin with January issue.

Advertisements accepted from reputable concerns at the following net rates:

Space	Less than half year per issue	Half year per issue	One year per issue
1 page	$50.00	$44.00	$40.00
½ page	30.00	25.00	22.00

Additional charges for Preferred Positions.

Changes of advertising copy should reach this office by the 10th of the month, for the issue of the following month.

Vol. XXVII **November, 1908** No. 11

November Meeting A. I. E. E.

The two hundred and thirty-first meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West Thirty-ninth Street, New York, on Friday, November 13, 1908, at 8 o'clock p.m. The subject to be discussed at this meeting will be announced by regular postal card notice, on Monday, November 9, 1908.

December Meeting A. I. E. E.

The December meeting will be held in the auditorium of the Engineers' Building on Friday, December 11, 1908. The subject to be discussed at this meeting will be announced in the December PROCEEDINGS.

Minutes of October Meeting of the Institute

The two hundred and thirtieth regular meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West Thirty-ninth street, New York, Friday, October 9, 1908. President Ferguson called the meeting to order at 8 p.m.

The secretary announced that at the meeting of the Board of Directors held during the afternoon there were 112 Associates elected, as follows:

BALLARD, ALFRED H., Master Operator, Pacific Electric Railway; res., 647 Ceres Ave., Los Angeles, Cal.

BALLARD, ARTHUR WALTER, Manager, Los Angeles Office, Gen. Elec. Co., Delta Bldg., Los Angeles, Cal.

BATCHELDER, CHARLES KELSEY, Electrical Engineer, Central Colorado Power Co.; res., 432 N. Nevada Ave., Colorado Springs, Colo.

BATCHELDER, WILLIAM OSGOOD, Northern Texas Traction Co., Fort Worth, Texas.

BATES, CLIFFORD WHITMAN, Instructor in Electricity, Sheffield Scientific School of Yale University, New Haven, Conn.

BEALS, FREDERICK HALL, Professor of Physics, Occidental College, Los Angeles, Los Angeles, Cal.

BENZIGER, JAKE ULRICH, Engineer in charge of Power Station, with Guinle & Co., Bahia, Brazil, S. A.

BOSSERT, CHARLES PHILIP, Mechanical Engineer, with Pfister & Vogel Leather Company, Milwaukee, Wis.

BOXALL, WILLIAM L., Power Contract Agent, The Edison Electric Co., Los Angeles, Cal.

BRANDENBURG, THEODOR, Superintendent, Cia Electrica y Irrigadova, Pachuca (Hidalgo), Mexico.

BRAUN, CARL FRANKLIN, Sales & Erecting Engineer, The Standard Electrical Works, 121 New Montgomery St., San Francisco, Cal.

Brill, Oscar Charles, Electrical Engineer, Radio Telephone Co., Wall St. Exchange Bldg., New York City.

Campbell, Claude Hornor, Bonding Foreman, Los Angeles Railway Co.; res., 425 W. 55th St., Los Angeles, Cal.

Campbell, David E., Sales Engineer, Stromberg-Carlson Telephone Mfg. Co., 526 Hayward Ave., Rochester, N. Y.

Carleton, Lindsay Ferguson, Substation Attendant, The Southern Power Company, Davidson, N. C.

Chesrown, Elias, Salesman, Westinghouse Electric & Mfg. Co., Union Bank Bldg., Pittsburg, Pa.

Clarke, Alexander, Superintendent of Electrical Department, So. Penn Oil Co., Folsom, W. Va.

Clements, Oscar S., Asst. Electrician, Electrical Dept., Panama Ry. Co., Cristobal, Canal Zone, Pan.

Cox, Joseph Harris, Salesman, Bailie & Brandt Co., 943 N. Main St., Los Angeles, Cal.

Cursset, Pheros D., Chief Engineer, Compania Ituaua Forca e Luz, Itu, Sao Paula, Brazil, S. A.

Daggett, Parker Hayward, Assistant in Electrical Engineering, Harvard University; res., Neponset, Mass.

Dalton, Walter, Electrical Engineer, Philadelphia Electric Construction Co., 914 Filbert St., Philadelphia, Pa.

Darling, George F., Traveling Salesman, Electrical Engineering Co.; res., Hampshire Arms, Minneapolis, Minn.

Darnell, William Henry, General Foreman, Underground System, The Edison Electric Co., Los Angeles, Cal.

Darrall, Stephenson S., Electrical Engineer, with J. K. Robinson, Iquique, Chile.

Dobson, Andrew Edward, Electrician, The Mt. Bischoff Tin Mining Co., Waratah, Tasmania.

Evers, Christian H., Foreman, Electric Meter Dept., Birmingham Ry., Light & Power Co., 2100 1st Ave., Birmingham, Ala.

Eyre, Richard. Patent Attorney, Kenyon & Kenyon, 49 Wall St., New York City.

Fahy, John Thomas, Electrician to the Department, New Zealand Govt. Railway, Wellington, N. Z.

Falk, Harold Sands, General Superintendent, The Falk Co.; res., 3125 Sycamore St., Milwaukee, Wis.

Farrand, Albert Clark, City Electrician, Atlantic City, N. J.

Fellechner, Frederick Gustav, Draftsman, Bridgeport Brass Co.; res., 231 Fairfield Ave., Bridgeport, Conn.

Foster, Fred. Fancher, Salesman, B. F. Kierulff, Jr. & Co., 210 Los Angeles St., Los Angeles, Cal.

Foulkes, Thomas, President, Foulkes-Gaylord Co., Inc., 931 Security Bldg.; res., 2374 W. Washington St., Los Angeles, Cal.

Francis, Ira Johnson, Manager, John A. Roebling's Sons Co., 1932 Hobart Blvd., Los Angeles, Cal.

Franz, Walter Godfrey, Consulting Engineer, Union Trust Bldg., Cincinnati, O

Gaylord, Robert H., Electrical Contractor, with Foulkes, Gaylord Co., Pasadena, Cal.

Geer, Francis Howard, Electrician, with Los Angeles Pacific Co.; res., 1451 Holmby Ave., Los Angeles, Cal.

Gettrust, John Steele, Salesman, Eck Dynamo & Motor Co., Belleville, N. J.; res., 4002 Elsmere Ave., S. Norwood, Ohio.

Gilbert, Lloyd Damond, Secretary and Chief Engineer, Cement Engineering Co., 1215 Union Trust Bldg., Los Angeles, Cal.

Glasgow, Alfred Stevens, Salesman, General Electric Co., 304 Delta Bldg., Los Angeles, Cal.

Gleason, Frederick John, Vice-president, Massachusetts Chemical Company, Walpole, Mass.

Glennie, Federico Trigueros, Civil Engineer, The Mexican Light & Power Co., Mexico City, Mexico.

Grant, William Maxwell, Engineer, Westinghouse Electric & Mfg. Co., 2d & Natoma Sts., San Francisco, Cal.

Gupta, Birendra Chandea, 57 Tregunter Road, So. Kensington, London, S. Eng.

Hall, Walter Douglas, Supt., Power Plant & Electrical Equipment, The Grand Trunk Ry. & St. Clair Tunnel Co., Port Huron, Mich.

Halloran, Arthur Hobart, Managing Editor, Journal of Electricity, Power & Gas, 111 New Montgomery St., San Francisco, Cal.

Hilleary, Orville, Chief Engineer of Power Station, Edison Electric Co., Los Angeles, Cal.

Hoag, Wright Sammis, Engineer and Salesman, Westinghouse E. & M. Co.; res., 527 S. Main St., Los Angeles, Cal.

Hoar, Frederick Emerson, Professional Electrical Engineer, 702 Metropolis Bldg., San Francisco; res., 916 Filbert St., Oakland, Cal.

Hughes, Robert James, Draftsman, Pacific Gas & Electric Co.; res., 978 Ellis St., San Francisco, Cal.

Ingham, Walter Prescott, Superintendent of Railway, Ponce Railway & Light Co., Ponce, Porto Rico.

Jackson, Chester H., Lineman, Los Angeles Gas & Electric Co.; res., 645 So. Hill St., Los Angeles, Cal.

Kean, Alonzo, General Construction Foreman, Pacific Electric R.R. Co. & Los Angeles Interurban R.R. Co., Los Angeles, Cal.

Kelman, Joseph Nelson, President, Kelman Electric & Mfg. Co.; res., 212 No. Sichel St., Los Angeles, Cal.

Kemp, Charles George Ridgely, with Guinle & Co., Caixa do correio, No. 2, Petropolis, Rio de Janeiro, Brazil.

Kensit, Henry Edward Mordaunt, Chief Assistant, Smith, Kerry & Chace, Confederation Life Bldg., Toronto, Ontario.

Kirschberg, Harold, Engineer, P.R.R. Co.; res. 1412 11th St., Altoona, Pa.

Lidders, Alexander Henry, Patent Attorney, Brooks & Lidders, 615 L. A. Trust Bldg., Los Angeles, Cal.

MacDonald, George W., Electrician, City of Los Angeles; res., 3113 Dalton Ave., Los Angeles, Cal.

Manahan, Roland Harry, City Electrician, City Hall; res., 2416 Echo Park Ave., Los Angeles Cal.

Mastin, Francis Wells, Engineer, Plant Dept., The New York Telephone Co., Piermont, N. Y.

McKibbin, Robert H., Chief Electrician, Palmer Mountain Tunnel & Power Co., Loomis, Washington.

Millar, Hawthorne McKenzie, Student, Wellington, N. Z.

Möller, Nils André, Draughtsman, The Mexican Light & Power Co., Ltd., Mexico City, Mexico.

Moore, Nelson Sheppard, Clerk in General Sales Dept., Western Electric Co., Chicago, Ill.

Murray, Henry Hall, Switchboard Constructor, Guinle & Co., Correio Caixa No. 2, Petropolis, Rio de Janeiro, Brazil.

Myers, Albert Sylvester, Assistant Engineer, Home Tel. & Tel. Co., 716 S. Olive St., Los Angeles, Cal.

Neiswanger, Ellis Barton, Chief Electrician, The United States Reduction & Refining Co., 111 So. 11th St., Colorado Springs, Colo.

Noble, James F., Engineer, Pioneer Tel. & Tel. Co., Pioneer Bldg., Oklahoma City, Oklahoma.

Ogle, Thomas B., Supt. of Elect. Division, Norfolk & Southern Railway; res., 723 28th St., Park Place, Norfolk, Va.

Payne, Lewis, Superintendent of Light Plant, The Allegheny Pin & Bracket Co., Covington, Va.

Peeples, Ben, Electrical and Railway Constructor, Memphis, Tenn.

Porter, Emery D., Superintendent of Fire Alarms and Electrical Inspector, Lewiston, Mont.

Pyle, Clarence G., Representative, Standard Underground Cable Co.; 913 Union Trust Bldg., Los Angeles, Cal.

Reed, Robert Rentoul, General Manager, Washington & Canonsburg Ry. Company, Washington, Pa.

Reeve, John Wright, Jr., Superintendent, Lake City Water & Light Plant, Lake City, Fla.

Rojahn, Elmer Ewalt, Switchboard Operator, Edison Electric Light Co., York; res., Dallastown, Pa.

Roome, William Guernsey, 940 W. 20th St., Los Angeles, Cal.

Rosok, Ingwald A., Electrical Engineer, Bisbee Improvement Company, Bisbee, Arizona.

Ross, Edward Jackson, Jr., Salesman and Experimenter, Edison Storage Battery Co., Orange, N. J.

Sandford, Joseph Addison, Jr., Sales Manager, The New Lexington High Voltage Porcelain Co., New Lexington, O.

Sawtelle, Edmund Monroe, Territorial Sales Manager, British W. E. & M. Co., Trafford Park, Manchester, Eng.

Scattergood, Ezra Frederick, Consulting Electrical Engineer, Los Angeles Aqueduct, 1133-1134 Central Bldg., Los Angeles, Cal.

Seaman, John H., Superintendent, Glendale Light & Power Co., Tropico, Cal.

Servos, John, Chief Operator, Toronto & Niagara Power Co.; res., 254 Ossington Ave., Toronto, Ont.

Shortall, Oliver Randall, Construction Dept. Engineer, Electric Storage Battery Co., Allegheny Ave. & 19th St., Philadelphia, Pa.

Smith, William Brown, Electrician, Los Angeles Aqueduct; 1134 Central Bldg. Los Angeles, Cal.

Socci, John B., Electrical Constructor, Mexican Lt. & Power Co., Ltd., 14a de Zarco, 3314, Mexico, City, Mex.

Stahl, Nicholas, Corresponding Engineer, Westinghouse E. & M. Co., Pittsburg, Pa.

Stambaugh, Ralph Waldo, Chief Electrician, Republic Iron and Steel Co. res., 135 Silver St., Youngstown, O.

Stone, Ernest Frank, Supt. of Line Construction, Norfolk & Ports. Traction Co; res., 9 Redgate Ave., Norfolk, Va.

Sutherland, Kenneth Wallace, Managing Engineer, Todd & Samuel, 65 Brookman's Bldg., Adelaide, South Australia.

Swann, Theodore, Owner and Engineer, The Swann Electric Company, Bristol, Tenn.

Taber, Edmund Rhett, Jr., Electrician, The Flaketown Graphite Co., Mountain Creek, Alabama.

Tate, John Victor Edward, Chief Line Inspector Cauvery Power Scheme, Kankahalli, Mysore India.

Tellington, Jesse James, Electrician, Berlin Electric Light Co., Berlin, New Hampshire.

Thompson, Dwinel Burt, Testing Department, Gen. Elec. Co.; res., 225 Union St., Schenectady, N. Y.

Tryon, Allan C., Superintendent, Maumee Electric Co., Maumee, O.

Twining, Harry LaVerne, Teacher of Physics and Elec. Eng., Los Angeles Polytechnic High School; Los Angeles, Cal.

Van Horne, John S., Electrician, U. S. Immigration Service, Ellis Island; res., 617 W. 152d St., New York City.

Walton, Frank Porter, Chief Operator, Los Angeles Gas & Electric Co.; res., 516 E. 25th St., Los Angeles, Cal.

Watson, Lionel, Electrical Dept., Dominion Automobile Co., res., 238 Lisgar St., Toronto, Ont.

Watts, George Edwin, Southern Manager, Electric Service Supplies Co., 107 So. Forsyth St.; res., 230 Peeples St., Atlanta, Ga.

Weller, Harold Fraser, Secretary and Treasurer, South California Drilling & Construction Co.; Los Angeles, Cal.

Wilson, Harry Curtis, Superintendent of Government Telegraph, Kingston, Jamaica, British West Indies.

Wilson, Joseph Lupton, with Guinle & Co., Avenida Central 109, Rio de Janeiro, Brazil.

Wintersgill, Harry Livingstone, Assistant Electrical Engineer, The Pacific Light & Power Co.; res., 1211 So. Union Ave., Los Angeles, Cal.

Woehler, William L., Electrical Engineer, Goldfield Consolidated Mines Co., Goldfield, Nev.

Young, Harry Paulding, Office Manager, Electrical Equipment Co., res., Preston Apts., Atlantic City, N. J.

Zetherlund, Carl Adolf, Electrical Engineer, Kashmir State Government, Baramulla, Kashmir, India.

Ziegler, Guy, Electrician, Westinghouse Lamp Co., Riverton, Neb.

The secretary announced further that the following Associates were transferred to the grade of Member:

Robert Albert Hadfield, Metallurgical Engineer, Mayfair W., England.

Edward Belden Merrill, Chief Assistant Engineer, Winnipeg Power Department, Winnipeg, Canada.

William Noble Dickinson, Jr., Manager Foreign Department, Otis Elevator Company, 17 Battery Place, N. Y. City.

Messrs. Peter Junkersfeld and E. O. Schweitzer of the Commonwealth Edison Company of Chicago then presented a paper entitled "High-Potential Underground Transmission." The paper was discussed by Messrs. C. H. Merz, H. W. Fisher, H. G. Stott, E. J. Berg, W. S. Clark, Alex Dow, Warren Partridge, E. E. F. Creighton, L. A. Ferguson, L. C. Robinson, Henry Floy, J. W. Lieb, Jr., Philip Torchio, C. P. Steinmetz, E. O. Schweitzer, Peter Junkersfeld and R. D. Mershon.

[The paper is printed in the October, 1908, Proceedings, pages 1463–1491; the discussion will be printed in the December, 1908, Proceedings.]

Formal Presentation of the Scott Testimonial at Atlantic City, June 30, 1908

Samuel Sheldon: "At a meeting of the Board of Directors of the American Institute of Electrical Engineers, held on February 14, 1908, upon the expiration of the three years' service of a trustee of the United Engineering Society, the Board desired to put on record its hearty recognition of this trustee's earnest, faithful, and efficient services throughout the inception, construction, and completion of the Engineers' Building.

It therefore passed a set of resolutions to the effect: That to his engineering experience, to his watchful care, and to his thorough appreciation of the requirements of the future as well as of the present, and especially to his controling influence in bringing about the full realization of a plan, which, at the outset, seemed only visionary, the electrical engineers of America are, and will for all time, be indebted.

It was further resolved to this effect: That the American Institute of Electrical Engineers tenders its sincere thanks to this trustee for his devotion to its interests, throughout his term as a representative upon the Joint Building Committee, and upon the Board of Trustees of the United Engineering Society.

It is a great pleasure for me to-night in the presence of this large and representative attendance of the members of the Institute, to present an engrossed copy of the resolutions* to which I have referred, to that irrepressibly active past-president and past-trustee, Mr. Charles F. Scott."

Charles F. Scott: "The occasion for these resolutions relates to work covering several years, several of the most eventful years of my life. These resolutions will keep fresh in my memory my association with the members of the American Institute of Electrical Engineers, and particularly with its Board of Directors.

---

*A facsimile of the resolutions is printed on page 5 of Section I of the August Proceedings.

When I became president of the Institute, I little appreciated the scope, the work, and the possibilities of this organization. It was through contact with its directors and officers, gaining from them some of their ideals and inspiration, sharing their faith and foresight, their hope, and confidence in looking forward to the future—it was contact with them and gaining inspiration through their ideals and hopes that led me on in the work in which it has been my privilege to take part.

I feel that in coöperation with these men, and with the support of the Institute at large, there has been accomplished during these years something which has not only been at once notable, but will endure long into the future, making our Institute larger, enabling it to take its place and standing among the other engineering societies, and making the electrical engineer, and the engineer in general, a new factor, a larger factor, in the progress of our country and in its civilization.

I thank you, Dr. Sheldon. I appreciate deeply this testimonial from my associates, those who have assisted in the work which this certificate commemorates. It is interesting to note that the date which it bears is February 14, just five years later than the St. Valentine's day on which Mr. Carnegie wrote his first letter of gift.

I will cherish this not only for what it shows on its face, but for the spirit which has inspired it, because it testifies to some of the warmest friendships and associations which I have formed with this Board of Directors, with members of the Institute, and with members of the other engineering societies with whom the Institute work has been associated in the past few years."

After ten years practice in large American and German concerns, Mr. Eugene Eichel, of Berlin, S. W., Germany, has established himself in that city as consulting engineer, with an office at Alte Jacobstr. 106.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before December 1, 1908.

7883 Sprague, R. V., Electron, Wash.
7884 Rutherford, J. W., Jersey City.
7885 Leilich, F. T., So. Bethlehem, Pa.
7886 Cadwell, Wm., Chicago, Ill.
7887 Jackson, J. A., Schenectady, N. Y.
7888 Denton, F. M., Pittsburg, Pa.
7889 Sinclair, S. L., New York City.
7890 Dodds, J. S., Indiana, Pa.
7891 Newman, A. C., New York City.
7892 Centerwell, T. G. J. D., Gullspang, Sweden
7893 Leonard, Chas., Baltimore, Md.
7894 Hibner, A. E., Rochester, N. Y.
7895 Watley, W. F., Portsmouth, Va.
7896 Smith, J. L., Leadville, Colo.
7897 Leonard, J. A., Ellsworth, Me.
7898 Shaughnessy, J. J., N. Y. City
7899 Tompkins, W. M., E. Lansdowne, Pa.
7900 Carter, Capt. C. C., Boston, Mass.
7901 McIlheran, W. C., Birmingham, Ala.
7902 Chilton, St. J., Philadelphia, Pa.
7903 Frost, D. K., New York City.
7904 Ruel, A. J., Boston, Mass.
7905 Schnabel, J. F., New York City.
7906 Bozell, H. V., Norman, Okla.
7907 Conlin, Jos., Toledo, O.
7908 Knoener, H. A., Ampere, N. J.
7909 Stovall, S. L., Visalia, Cal.
7910 Bell, W. I., Jersey City, N. J.
7911 DeLay, F. A., Ann Arbor, Mich.
7912 Castle, S. N., New York City.
7913 Strong, G. W., Cleveland, O.
7914 Wiatt, H., Los Angeles, Cal.
7915 Wintrode, E. B., Los Angeles, Cal.
7916 Guell, Entonio, Urbana, Ill.
7917 Lebovici, J., Mansfield, O.
7918 Gaskill, W. W., Cambridge, Mass.
7919 Carter, G. R., Cambridge, Mass.
7920 Whitehurst, O. F., Chicago, Ill.
7921 Mervine, G. S., New York City.

7922 Tisell, G., New York City.
7923 Nein, W. C., Champaign, Ill.
7924 Banta, E. J., Culebra, Canal Zone.
7925 Mathewson, A., Henry Clay P. O., Delaware.
7926 Sked, N. S., Pennington, N. J.
7927 Walton, J. G., Oklahoma City, Okla.
7928 Rathbone, R. L., Cleveland, O.
7929 Aspestrand, Talle Hagbart.
7930 Ingleby, J. C. B., Leeds, England.
7931 McCabe, E. F., Lewiston, Pa.
7932 Reilly, W. F., New York City.
7933 Clark, J. A., Schenectady, N. Y.
7934 Parsons, E. D., Saratoga, N.Y.
7935 Elmes, C. F., New York City.
7936 Snook, J. J. A., Ft. Wayne, Ind.
7937 James, L. V., Champaign, Ill.
7938 Kingsbury, N. C., Detroit, Mich.
7939 Parker, Arthur, Camden, N. J.
7940 Bush, E. F., Mechanicsburg, Pa.
7941 Ball, Albert, New York City.
7942 Fisher, H. H., Chicago, Ill.
7943 Elkins, B. H., S. Windham, Me.
7944 Harris, R. W., Madison, Wis.
7945 Saathoff, G. W., St. Louis, Mo.
7946 Hillebrand, W.A., Stanford Univ., Cal.
7947 Powell, W. H., Milwaukee, Wis.
7948 Blackwell, O. B., N. Y. City.
7949 Keveney, T. S., Brooklyn, N. Y.
7950 Hart, Leon O., Harrison, N. J.
7951 Sleeth, M., Wilmerding, Pa.
7952 Johnson, K. S., Cambridge, Mass.
7953 Staunton, Gray, Chicago, Ill.
7954 Hollister, V. L., Lincoln, Neb.
7955 Hail, J. C., Chicago, Ill.
7956 Foote, E. T., Milwaukee, Wis.
7957 Aoyagi, Eiji, Kyoto, Japan.
7958 Hammer, M. R., Madison, Wis.
7959 Herdegen, R. T., New Orleans, La.
7960 Reiff, G. E., Chicago, Ill.
7961 Talbot, E. D., Bath, N. Y.
7962 Van Meter, R. H., Mulberry, Fla.
7963 Neth, D. B., Waterbury, Conn.
7964 Coursol, A. G., Sorel, Que., Can.
7965 Lott, A. L., Jr., Omaha, Neb.
7966 Reid, C. R., Eugene, Oregon.
7967 Upham, W. H., Pittsburg, Pa.
7968 Weniger, W., Corvallis, Oregon.
7969 Wolf, Geo., New York City.

Total, 87.

Applications for Transfer

Recommended for transfer by the Board of Examiners, September 25, 1908. Any objection to these transfers should be filed at once with the secretary.

Frederick D Nims, Chief Operating Engineer, Mexican Light & Power Co., City of Mexico, Mexico.

Charles Roy McKay, Manager, Light & Power Department, Toledo Railways & Light Company, Toledo, O.

Standen Leonard Pearce, City Electrical Engineer, Electricity Works, Manchester, England.

Austin Burt, General Superintendent and Engineer, Citizens Gas & Electric Company, Waterloo, Iowa.

Edgar Buckingham Holden, Jr., Electrical Engineer, with Viele, Blackwell & Buck, 49 Wall St., New York City.

John Boswell Whitehead, Associate Professor, Applied Electricity, Johns Hopkins University; Consulting Electrical Engineer, Baltimore, Md.

Henry Edward Mordaunt Kensit, Electrical Engineer, 19 North St., Toronto, Canada.

George Carl Shaad, Associate Professor of Electrical Engineering, Massachusetts Institute of Technology, Boston, Mass.

James Edgar Miller, Electrical Engineer, Westinghouse Electric & Manufacturing Company, Pittsburg, Pa.

The Philadelphia Section,

BY PAUL SPENCER*

It is a great pleasure to-night to welcome you all at the first meeting for the year of the Philadelphia Section of the American Institute of Electrical Engineers. In beginning our year's work, it will be profitable to spend a few moments in considering what the general aim of this Section should be, and in looking back over what has been accomplished in the five years since its organization, as well as in outlining briefly the policy of the present Board, to whom you have intrusted its affairs for the coming year.

---

* Presented at a meeting of the Philadelphia Section, October 12, 1908.

What, then, should be the aim of a Section such as this? To carry it on represents a certain amount of work and entails on its members some degree of obligation, an obligation which bears most immediately, to be sure, upon its officers and managers, but which extends also to each and every member. Is this work worth while? Can we apply the test of a commercial age to it and say that it pays? We, all of us, find an increasing number of obligations forced upon us. Some of these obligations we must accept. They lie in our line of duty. Of the others, we should pick and choose, accepting only those which seem to be for our benefit. Where does the work of this Section come in? Clearly, we must believe that it pays, returning to each of us a potential value in excess of the time and effort spent, a potential value that can some time be cashed in in the shape of dollars and cents, or otherwise we would not be here. Personally, I believe that the obligation entailed partakes somewhat of the nature of a duty, and can also be assumed with confident expectation of benefits to follow. The Constitution of the American Institute of Electrical Engineers states its objects to be the advancement of the theory and practice of electrical engineering and of the allied arts and sciences, and the maintenance of a high professional standing among its members, and it furthermore provides for the formation of Sections for the purpose of more effectually carrying out the aims of the Institute.

We, all of us here, are electrical engineers, or are connected in some way with the work of this profession. We are all vitally interested in its success, but more particularly are we interested in our own individual and personal success therein, or in some work allied therewith. Our bread and butter, and the bread and butter of those dependent upon us, is involved in that personal success. Now, the work of the electrical engineer, or, in fact, of any engineer, is preeminently one of coöperation. It seems unnecessary to dwell on this obvious fact. Conceive, if you can, in this day of rapid progress in this most rapidly changing profession, of the absurdity of the electrical engineer who endeavored to practice his profession without keeping himself in touch with the ideas of his fellow workers. His tools are the knowledge which he may have of the principles of his profession, and the experience which he has gained in using these principles. The needed knowledge can hardly be obtained from text books, which become obsolete almost over night, but can be obtained only from the ideas and experiences of his fellow workers, given forth during the rapid progress of the day's work, in papers, discussions, and conversations. The PROCEEDINGS of the Institute represent the text books in their making, and must be followed continuously by those of us who would keep pace with the rapid progress of the profession. But the studying of text books and the reading of printed papers are not the only ways of acquiring the necessary knowledge. The interchange of ideas among men working in the same field forms one of the most important means of this education. Ideas gained in this way have an added value. They carry with them the lively interest which comes from the play of one personality upon another. They call forth questions and answers, and the discussion which follows helps to weed out such ideas as may have been too hastily formed from incomplete data, and to strengthen those which are essentially correct. It is, therefore, vitally important to an electrical engineer that he should associate himself with others in his same line of work, and in no way can such association be conveniently obtained except in some such organization as this.

But there is another important fact in reference to increasing one's knowledge, and that is that there is no surer way to test the accuracy of one's ideas to one's own satisfaction than to formulate them and to endeavor to put them in such shape as to carry conviction to the minds of others. I take it to be true that the attempt to write a paper on any subject, or the entering into a discussion with intelligent effort, will generally result in increasing the knowledge of the writer or speaker on that subject fully as much as it does his hearers. Not only, therefore, to gain knowledge from others should an engineer be anxious to associate with his co-workers, but also that he may solidify and clarify his own knowledge by giving it out to others. The opportunity of listening to papers and the expressed ideas of others is, therefore, one of the important advantages of such an organization as this. The opportunity of expressing his own ideas, and of gaining experience in presenting those ideas to others, is a second and still more important advantage.

There is a third advantage, and this is perhaps one that will appeal most readily to all of us, and that is that in such an organization it is possible to most easily extend one's acquaintance among his fellow engineers. It is, I think, clear that one's friends and acquaintances form a most valuable asset. I do not think that I will be misunderstood as placing a low or selfish value on friendship or acquaintanceship in emphasizing this point. I do not mean to intimate that we work our friends for our personal advantage, but in all walks of life we naturally turn for advice and assistance, or direct others for such assistance, to those whom we know and in whom we have confidence, based on a personal knowledge of their integrity, ability, and experience.

I, therefore, would say, to the younger members especially, take all the opportunity you can to form the acquaintance of the fellow workers in your chosen profession, both your contemporaries and especially those who are older and of larger and greater experience than yourselves. The personal advantages to be derived from such an organization as this, rightly used, lie in the opportunity for personal contact with other engineers, with the resulting increase in one's knowledge through the interchange of ideas, and in the extended acquaintanceship which this contact gives. It unquestionably should be the aim of this Section to endeavor to give to its membership these benefits.

I have dwelt briefly on the advantages which we may gain by associating ourselves with such an organization, but as members of the profession I feel that there also is entailed an obligation on us which we cannot rightfully shirk. One of the objects of the formation of the Institute, as expressed in its Constitution, in the paragraph which I have already alluded to, is stated to be the maintenance of a high professional standing among its members. As the recipients of benefits from the great body of our fellow engineers, we should feel a personal obligation in joining with its recognized organization, and in endeavoring through that organization to improve its personnel, to correct its code of ethics, written or implied, and to endeavor to increase its standing among the other great professions of the world.

Such, briefly, should be the aim of this Section, as a part of the American Institute of Electrical Engineers. The work of the past five years has shown in increasing measure a fulfilment of these ideas. The starting of the work was more or less feeble. Those of us who formed the organization had perhaps but slight acquaintanceship with each other. Each year has shown an increasing growth in the membership of the Section, in the numbers who have attended the meetings and in the interest shown in the meetings themselves. Each year, it can be safely said, has been better and more successful than the preceding one. We hope that this coming year may be still more successful, but to make it so we must have your coöperation.

Definitely we would outline the following policy:

1. We wish to increase the membership of the Institute, and of this Section, by adding as members all not now members who may be eligible.

2. Along this line, we wish to interest the electrical engineering students of the various technical institutions in our territory, as in this class is included the most desirable material for future membership in the Institute. To this end, I have appointed a special Committee on Students.

3. We want an even better attendance at the dinners, and a greater increase in the sociability of our meetings, The accomplishment of this purpose lies largely in the hands of the individual members.

4 We hope to make the meetings deal largely with subjects that will be of local interest, presented by representatives of Philadelphia's important electrical interests.

5. We desire particularly to have a more general discussion, and to extend the active participation in the meetings among as many as possible of those who have not before taken an active part, and particularly among the younger men. To this end, we hope to be able to lay out later in the season one or two evenings that will be given over to topical subjects in such a way as to include a large number in the presentation of the papers and the discussion thereon.

In conclusion, you will see that the above program will entail upon the management the necessity of making the evenings of interest to its membership, but will also require the assistance of the members themselves. If any further argument be needed to enlist your coöperation, I would appeal to your pride in Philadelphia as a centre of electrical interests. We have just passed through a week of delirious celebration. Now that the tumult and the shouting has died, there cannot help but be left in our minds an increased pride in our city, as we have had brought to our attention the splendid background of tradition which is hers. Let me also refresh your minds by calling attention to the fact that among the other first things which happened in Philadelphia, though not included in the gorgeous pageant of last week, was the first meeting in this city, twenty-four years ago, in this very month of October, of the American Institute of Electrical Engineers. The Philadelphia Section was not the first of the branch organizations of the Institute to be formed, but it has taken a front rank among all the Sections as endeavoring to carry out in its own membership those ideals which the Institute as a whole represents to the entire profession. Gentlemen, we ask you to give us your coöperation in maintaining that position.

Sections and Branches

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

At the first meeting of the school year for this Branch, held in Chapin Hall, Oct. 1, Mr. P. G. Downton read a paper on "Booster Systems." This paper dealt entirely with boosters used in connection with storage-battery installations. Each type was taken up and explained in detail by means of diagrams. Special stress was laid upon the automatic types, both reversible and non-reversible. The speaker cited cases where boosters were used, and gave interesting figures showing the improvement and saving in the service rendered. The size of the plant in relation to the system employed was taken up and the speaker pointed out the conditions governing this choice. The use of storage-batteries in connection with alternating-current installations was touched upon and some of the booster schemes used were explained. In the discussion following the reading of the paper, Mr. Simpson explained in detail the split-pole synchronous converter and its relation to alternating-current central station economy.

BALTIMORE SECTION

The Baltimore Section held a meeting on October 9. 1908, Dr. J.B. Whitehead presided, and there was an attendance of 25 members and 16 visitors. Dr. Whitehead presented his report as delegate to the Atlantic City convention of the Institute. This was followed by a review of Mr. E.J. Berg's convention paper "Tests with Arcing Grounds and Connections," by Mr. Carroll Thomas. Dr. L. M. Potts reviewed Mr. Reginald Fessenden's paper on "Wireless Telephony."

CLEVELAND SECTION

The Cleveland Section held its opening meeting of the year in the Case School of Applied Science, Electrical Building, Monday, September 21, 1908, Mr. C. W. Ricker presiding. There was an attendance of 36. Mr. Ricker brought up for discussion a proposition for securing a more suitable meeting place, which was not acted upon, but left in the hands of the executive committee. The subject of the evening, "Some Tests Made by the Brooklyn Rapid Transit Company to Predetermine the Load on an Elevated System," was very ably presented by Mr. H. L. Wallau, who had charge of this work. Some discussion followed, several traction men present taking part, making the meeting very interesting and instructive.

FORT WAYNE SECTION

The first regular meeting of the Fort Wayne Section was held at the offices of the Fort Wayne Engineering Company, Michael Building, Mr. E. A. Wagner presiding. There was a fairly good attendance of the members of the Section, and the meeting was of a purely business nature. The organization committee submitted a set of by-laws which were considered and adopted. The following officers were elected for the year 1908-1909: E. A. Wagner, chairman; J. J. Kline, vice-chairman; J. V. Hunter, secretary; executive committee, T. R. Cook, C. H. Kelsay, and F. S. Hunting.

The second regular meeting of the Section was held Thursday evening, October 8, 1908. The meeting was preceded by an enjoyable dinner at the Homestead Cafe. A large percentage of the members were present and there were a number of visitors. The meeting was called to order by the chairman, Mr. E. A. Wagner, and discussions on two subjects of interest were opened by members giving a résumé of the recent papers upon these subjects. The first, "Lightning Arresters and Lightning Phenomena" was taken up by Mr. Earl B. Hoff and followed by a discussion. The second, "Water Power Development," was taken up by Mr. Walter Kent and an animated discussion followed, most of the members present taking part.

The question of the continuance of the policy of having a dinner before the meetings was brought up and it was decided to try it for some months in order to see whether it would be practicable to continue. It was the opinion of all the members present that this would be a very enjoyable feature with which to open an evening of business.

LOS ANGELES SECTION

The Los Angeles Section held its regular meeting on Tuesday, September 15, 1908, at the University of Southern California. There were present 24 members and 58 visitors. The executive committee reported the election of the following officers: C. W. Koiner, chairman; J. E. MacDonald, secretary, and Ed. Woodbury, assistant secretary. Mr. J. R. Atchison, superintendent of construction, with Charles C. Moore & Company, presented a paper on "A Modern Steam Power Central Station." The following members participated in the discussion that followed: Messrs. T. A. Panter, Ralph Bennet, V. L. Benedict, C. A. Copeland and J. A., Lighthipe.

MONTANA AGRICULTURAL COLLEGE BRANCH

A meeting of this Branch was held in the electrical lecture room on Friday, October 9, 1908. There was an attendance of 20. Mr. W. G. Kirscher read an interesting paper on "Review of the Year's Work of the Institute." This was followed by an experimental lecture on electrolytic rectifiers, by Mr. P. C. Rawls. Mr. Rawls said that his attention was first called to the subject by an article of a German scientist, on a peculiar property of aluminum when used as an electrode in an electrolytic cell; namely, the difference in the resistance of the electric current when passed through the cell from the aluminum to the neutral electrode; being less than when flowing from the neutral to the aluminum electrode. Mr. Rawls gave a scientific explanation of the cause of this difference, illustrating it with a number of interesting experiments. The experiments were conducted with simple aluminum cells and a small rectifying set.

NORFOLK SECTION

The first fall meeting of the Norfolk Section was held in the city electrician's office, Williams and Talbott streets, on October 9, 1908. The chairman, Mr. D. G. Stanbrough, presided, with an attendance of 21. There being no business before the Section, and no papers presented, Mr. Stanbrough gave a long and interesting talk on the design of circuits and the installation of underground cable systems.

PHILADELPHIA SECTION

The forty-eighth meeting of the Philadelphia Section was held on October 12, 1908, in the meeting room of the Philadelphia Electric Building. There was a total attendance of 70. Mr. Paul Spencer presided, and delivered an address relating to the work of the Section. In touching upon the general aim of the Section, Mr. Spencer reviewed the work that had been accomplished in the five years since its organization, and outlined briefly the policy for the future.

Mr. W. C. L. Eglin presented the report of the Institute convention committee, and stated that after all debts had been paid and a refund of approximately 50% made to each subscriber to the convention fund, a balance of $50 remained. Mr. Eglin offered this balance to the Section, and it was accepted.

The following committees were appointed: Papers, Membership, Editing, Reception, Dinner, Students, and Advisory. Mr. Day made a few remarks on the work of the papers committee and requested the coöperation of the members.

The paper of the evening, "Increasing the Output and Economy of a Non-Condensing Station by the Use of Exhaust Steam Turbines", by Messrs. W. S. Twining and W. C. Kerr, was presented by Mr. Kerr. The paper was illustrated by lantern slides, and an animated discussion followed, in which the following gentlemen participated: Messrs. Porter, Weeks, Stevens, Dodge, McFarren, Hornor, Dyatt, Spencer, Cheyney, Temple, Painter, Bibbins, and Klumpp.

PITTSBURGH SECTION

The regular October meeting of the Pittsburgh Section was held in the lecture hall of the Carnegie Institute on the 13th. Seventeen members attended the informal dinner held at the University Club immediately preceding the meeting. The evening was devoted to the presentation and discussion of two original papers. The subject of the first paper was "The Oscillograph and Some of Its Uses," by Mr. H. H. Galleher, engineer of the high tension testing laboratory of the Westinghouse Electric & Manufacturing Company, and the second, "The Testing of Large Alternating Current Generators", by Mr. L. E. Schumacher, of the dynamo testing department of the same company. The papers were illustrated by lantern slides. Mr. Galleher's paper dealt with the practical application of the oscillograph to everyday problems and explained its general construction, operation, adjustment and repairs. Professor S. M. Denton, of the Carnegie Institute. supplemented Mr. Galleher's paper with a talk on the application of the oscillograph to the solving of complex problems in phase relation, and showed how essential this instrument has become in large power transmission plants as a means of explaining perplexing phenomena. He advocated the purchase of such instruments by high tension central stations generally. Mr. Denton then gave an interesting description of the Irwin Hot Wire Oscillograph, which, he stated, gives great promise as a cheap and sufficiently accurate instrument for such purposes. The subject was further discussed by Messrs. R. P. Jackson, S. M. Kintner and A. W. Copley.

Mr. Schumacher's paper dealt particularly with the tests on the large 8770 kw., 12,000-volt, three-phase generators of the Ontario Power Company at Niagara Falls, which were tested after erection. The methods of testing and some of the results were given.

The paper was discussed by Messrs. P. M. Lincoln, W. L. Waters, F. D. Newbury and C. Renshaw, special comment being made on the water rheostat and the use of temperature coils to ascertain temperatures in places where thermometers could not be used.

PITTSFIELD SECTION

The Pittsfield Section held a preliminary meeting early in September, for the purpose of electing officers: The following were elected: W. A. Hall, chairman; H W. Tobey, secretary; executive committee, C. C. Chesney, W. S. Moody, J. Insull, H. L. Smith, S. H. Blake. It was planned to commence the regular meetings for the season the last week in October or the first week in November.

PURDUE UNIVERSITY BRANCH

The Purdue University Branch held its first meeting of the season September 22, 1908, in the lecture room of the Electrical Building, with an attendance of 38, vice-chairman J. R. Ong presiding. In his opening remarks Mr. Ong urged that the enrolled students take greater part in the discussions of subjects of papers presented before the Institute. Mr. E. S. Baker, who for the past five years has been connected with the General Electric Company, then gave a very interesting talk on that company, describing in detail the course given there to college students and other men of technical training. Mr. Baker went very thoroughly into the subject, and many questions were asked him respecting the plant and social conditions at Schenectady

SAN FRANCISCO SECTION

This Section held a meeting on July 24, 1908, which was presided over by Mr. P. M. Downing, there being an attendance of 83. The subject of the evening was a paper by Mr. F. E. Vickers, entitled " The Curtis Turbine." It was decided to hold no meeting in August.

SEATTLE SECTION

The Seattle Section opened its business of the season on September 19, 1908, with an informal dinner in the banquet room of the Seattle Athletic Club. After an enjoyable repast plans for the coming season were discussed. The subject of local membership received a considerable share of attention. This was followed by a pleasing address by the chairman, Mr. J. Harisberger, who was the Seattle delegate to Atlantic City, giving his impressions of the convention. An invitation extended by the Automatic Telephone Company to the members of the Section to make an inspection trip to the Tacoma " girlless " central office, was read, and it was decided to accept the invitation and make the trip in place of the regular November meeting.

STANFORD UNIVERSITY BRANCH

This Branch held a meeting on September 28, 1908, there being an attendance of 16. Professor S. B. Charters, who conducted a series of tests for the Westinghouse Electric & Manufacturing Company some years ago, gave an interesting talk on " Insulation Testing ", covering very thoroughly the difficulties encountered in the practical carrying out of such tests. He went at some length into the advantages and disadvantages of various kinds of insulation, and samples of the different materials, both before and after treatment, were exhibited.

SYRACUSE UNIVERSITY BRANCH

The first meeting of this Branch, for the year 1908–9, was held on October 15, 1908, Mr. W.P. Graham presiding. Mr. H. G. Hopkins gave an abstract of the Institute paper by J. F. Vaughn, on "Comparative Tests of Lightning Protective Devices." Mr. W. J. Stube abstracted the paper by Mr. N. J. Neall, on "Studies in Lightning Performance, Season of 1907." A general discussion of these papers followed. The secretary announced a proposed plan for the establishment of a local membership list for those desiring to become members of the Branch, who are not members of the Institute. Final action was deferred.

TOLEDO SECTION

The Toledo Section opened its season by holding a banquet at the Boody House, Friday evening, September 11. Mr. M. W. Hansen, chairman of the program committee, had charge of the arrangements, and after an excellent dinner, acted as toastmaster. In well chosen words Mr. Hansen emphasized the extent of the work of Mr. H. B. Dorman in organizing and bringing the Section to its present state of usefulness. In recognition of this work, as well as Mr. Dorman's services as chairman of the membership and executive committees, a resolution was passed tendering him the thanks of the Section. As a further expression of appreciation of the members, Mr. Dorman was presented with a gold-handled umbrella, which was suitably engraved. In the general conversation which followed Mr. Hansen's remarks, the future work of the Section was outlined. Mr. George E. Kirk, who represented the Section at the Atlantic City convention, then responded to an invitation to outline the attitude of the Institute towards Sections. Mr. Kirk detailed the action taken at the Sections meeting at the convention, held under the auspices of the Sections Committee, and concluded with a general account of the convention, which was listened to with much interest.

The regular monthly meeting was held on Friday, October 2, 1908, in the Builders Exchange. After the routine business had been transacted, Father Hillig, of St. John's College, delivered an entertaining address on the aurora borealis, recently quite noticeable. Father Hillig went into a scientific explanation of the cause of the phenomena, which was both entertaining and instructive.

In discussing the regular subject of the evening, Mr. George E. Kirk explained the origin of the term "patent", touching upon the early monopolies existing thereunder, and the development of the present patent system for inventions. The organization and operation of the United States Patent Office was also explained, and in order to bring out more clearly the points discussed, quite a number of patents were exhibited for examination.

UNIVERSITY OF CINCINNATI BRANCH

A meeting of this Branch was held on September 29, 1908. Mr. C. Wylie presided, and there was an attendance of 16. Mr. Wylie was re-elected chairman, and Mr. C. A. Winder was elected secretary. A paper was read by Messrs. Brandt and Balman on the induction motor and the application of the circle-diagram.

UNIVERSITY OF KANSAS BRANCH

This Branch held a meeting on October 8, 1908, and there were present 33 members and guests. Mr. L. V. Palmer reviewed the convention paper of Mr. Reginald Fessenden on "Wireless Telephony." Professor M. E. Rice reviewed the paper by Messrs. Kennelly and Whiting, on "The Measurement of Rotary Speeds of Dynamo Machines by the Stroboscopic Fork." Mr. Burton McCollum described the stroboscopic method he had used in studying the slip of induction motors. A general discussion followed each paper.

UNIVERSITY OF MISSOURI BRANCH

The University of Missouri Branch held its first meeting of the year on October 10, 1908, at Columbia, Professor H. B. Shaw presiding, with a total attendance of 14. The officers of the preceding year were re-elected. The chairman outlined the purpose and the scope of Institute work and urged upper classmen particularly to become active members of the Branch. It was thought best that those present be constituted a committee of the whole to arouse interest and increase the membership. Decision as to conduct of local meetings is to be made at an early date.

UNIVERSITY OF TEXAS BRANCH

The first meeting of this Branch was held Friday night, October 9, 1908. Eighteen members and visitors were present. The following officers were elected for the ensuing year: A. C. Scott, chairman; B.E. Kenyon, secretary and treasurer. An executive committee of three members was appointed.

A paper entitled " Commercial Insulation of Wire ", was read by the secretary, and proved interesting and instructive. This paper was furnished through the courtesy of the International Lecture Institute of New York.

URBANA SECTION

A meeting of this Section was held at the University of Illinois on the evening of October 7, 1908, with an attendance of 58. Officers for the following year were elected as follows: Professor Ellery B. Paine, chairman; Professor E. H. Waldo, vice-chairman; Mr. E. I. Wenger, secretary; Mr. F. G. Willson, treasurer.

Professor Morgan Brooks and Mr. J. M. Bryant made a report of the Atlantic City convention of the Institute. Professor Ellery B. Paine gave an account of his travels in Europe during the past summer. He described in detail an electric power plant which is an example of the best engineering in northern Italy. This plant is located at Zogno on the southern extremity of the Bergamesque Alps. The distinctive features of this plant are: the evidence of most careful study of even the smallest engineering details, the substantial character of all the construction work, the pleasing architecture of the station building, the harmonious coloring and decoration of the interior, and the elastic steel towers placed on the crests of the elevations to support the transmission wires in long spans across the ravines and valleys.

WASHINGTON SECTION

A meeting of the executive committee of the Washington Section was held on September 11, 1908. Mr. H. C. Eddy was elected secretary of the Section, succeeding Professor Louis D. Bliss, who was elected last spring, and found it impossible to accept the office on account of pressure of other duties. It was proposed to frame a new set of by-laws to govern the Section, and it was decided to call a meeting early in October for this purpose.

WASHINGTON UNIVERSITY BRANCH

The first meeting of the Washington University Branch for the new school year was held in Cupples Hall II on the afternoon of October 7, 1908. C. M. Duncan presided. There were nine members present; no visitors. The only business transacted was the election of H.F. Thomson, of the junior class, to the office of secretary-treasurer. The advisability of holding some of the meetings at night, instead of all in the afternoon, was discussed. This would enable the members to hear addresses by prominent engineers in the city who are too busy to attend in the daytime. The plan met with general approval among those present.

WORCESTER POLYTECHNIC BRANCH

The first meeting this year of the Worcester Polytechnic Branch was held Friday night, October 9, 1908, in the lecture hall of the Electrical Engineering Building. There was an attendance of 60. Mr. A. R. Powers, who was on the apprenticeship course with the Westinghouse Electric and Manufacturing Company during the summer of 1906, spoke very interestingly of his work in various departments of that company, and concluded by summing up the advantages to be obtained from such a course. Mr. W. A. Darrah gave a talk on " Some Impressions of the U. S. Patent Office." He spoke of taking the oath of office and of his introduction to his duties, laying especial stress upon the pleasant associates in the work, and the agreeable surroundings. His description of the classification of the work was humorous and interesting. He very clearly described the process of examining a patent, mentioning some interesting incidents illustrating the operation, in conclusion touching upon the advantages and disadvantages of this particular kind of work. Mr. D. H. Mace, who since his graduation has been in the testing department of the General Electric Company, gave an instructive and detailed account of his year's experience, describing the classification and conduct of the work. Other subjects touched upon by Mr. Mace were, construction and assembling work, testing railway motors, floor tests on small machines, and motor-generators. Mr. R. T. Pollock spoke on " Some Experiences with the Boston Elevated Railway Company." He told of his work as pitman; then in the inspection department, inspecting motors; later, on general inspection; and finally, with the electrical engineer. The paper gave an interesting account of several special tests and described many features of the Boston Elevated system. Professor H. B. Smith spoke briefly on the advantages to be derived from being an enrolled Student of the Institute.

Electrical Engineers

TECHNOLOGIC BRANCH, UNITED STATES GEOLOGICAL SURVEY

NOVEMBER 9, 1908

The United States Civil Service Commission announces an examination on November 9, 1908, to secure eligibles from which to make certification to fill a vacancy in the position of electrical engineer in the Technologic Branch, Geological Survey, at a salary ranging from $1,620 to $3,000 per annum, according to the rating received, and vacancies requiring similar qualifications as they may occur.

Competitors will not be assembled for any of the tests.

It is desired to secure persons who have had broad training and experience in electrical engineering, especially in connection with coal mining operations, and who will be fully qualified to undertake original investigations into the conditions under which electricity may be safely used in coal mining.

The examination will consist of the subjects mentioned below, weighted as indicated:

Subjects.	*Weights.*
1. Education and technical training, including postgraduate work...	35
2. Technical or professional experience in electricity as applied to coal mining.....................	35
3. Experience in general electrical work.....................	30
Total....................	100

Age limit, 21 years or over on the date of the examination.

This examination is open to all citizens of the United States who comply with the requirements.

This announcement contains all information which is communicated to applicants regarding the scope of the examination, the vacancy or vacancies to be filled, and the qualifications required.

Applicants should at once apply to the United States Civil Service Commission, Washington, D. C., for application Form 304 and special form. No application will be accepted unless properly executed and filed with the Commission at Washington prior to the hour of closing business on November 9, 1908. In applying for this examination the exact title as given at the head of this announcement should be used in the application.

Issued October 5, 1908.

Personals

Mr. James R. Wilson, formerly of New York City, is now residing at Niagara Falls, New York.

Mr. Walter L. Upson has accepted an appointment as assistant professor of electrical engineering in the Ohio State University.

Mr. Carl Wischmeyer has accepted the position of instructor in drawing at Rose Polytechnic Institute, Terre Haute, Ind.

Mr. F. K. Brainard has been appointed instructor in physics, and will have charge of the electrical measurements courses, at the University of Wisconsin.

Mr. S. R. Dodds, formerly an instructor in electrical engineering at Cornell University, is now in the West, and stopping temporarily at Seattle, Washington.

Mr. Douglas E. Black, of Montreal, and formerly with Albert B. Herrick, is now with the Illinois Traction System, in the motive power and equipment department, at Decatur, Ill.

Mr. Edward M. Bentley, who is now a member of the patent law firm of Betts, Sheffield, Bentley and Betts, has removed from 120 Broadway to 52 William Street, New York

Mr. William L. Coggin, formerly with the General Electric Company, at Lynn, Mass., is now with the Boston Elevated Railway Company, at the Charlestown power station.

Mr. H. W. Wilder, who recently completed a two-year contract with the Siamese government, at Bangkok, Siam, is now with the Southern Bell Telephone Company, at Atlanta, Ga.

Mr. James C. Dow, of Mankato, Minn., is doing special work in connection with the 20,000 h.p. steam plant and sub-station of the Helena Power Transmission Company, in Butte, Mont.

Mr. Ralph W. Krass, with the Campion McClellan Company, of New York, has been sent to Milford, N. J., as electrical and mechanical engineer, to look after the erection of a plant for a paper mill.

Robert H. Mitchell, formerly with the Twin State Gas & Electric Company, of Brattleboro, Vermont, is now in the employ of the Public Service Commission, First District, New York City.

Mr. Lawrence J. Gallagher has resigned from the physical science department of Wadleigh High School to accept an appointment in the examining division of the United States Patent Office.

Mr. Hugh A. Calderwood has been reappointed instructor in electric wiring in the Carnegie Technical Schools, Pittsburgh, which position he has occupied since the organization of the schools.

Mr. A. S. Loizeaux has left his position with the New York Edison Company and is now with the Consolidated Gas, Electric Light & Power Company at Baltimore, as electrical engineer.

Mr. A. J. Darrah has been appointed manager of the Van Wert Public Service Company, of Van Wert, Ohio. The company was formerly the Gas, Electric Light and Power Company of Van Wert.

Mr. C. W. Nickerson, Jr., recently with the Westchester Lighting Company Mt. Vernon, N. Y., as inspector of construction, has accepted a position with the American Boiler Company, Philadelphia, Pa.

Mr. C. I. Zimmerman has resigned his position as metallurgical engineer for the Carborundum Company, of Niagara Falls, to take up research work as a graduate student at the University of Wisconsin.

Mr. W. H. Carlin has left the firm of H. Eckstein & Company, of Johannesburg, to take over under lease and option the Moodie's Fortuna Gold Mining Company, Ltd., Barberton, Transvaal, South Africa.

Mr. Robert W. Adams, formerly assistant to the general manager of the D. & W. Fuse Company, at Providence, R. I., has joined the engineering staff of the General Electric Company at Pittsfield, Mass.

Mr. John H. Pearce has resigned his position on the engineering staff of the Missouri River Power Company, and is now electrical engineer of the Elkhorn Electrometal Company, Elkhorn, Montana.

Mr. R. T. Brooke has severed his connection with the Florida Electric Company, of Jacksonville, Fla., to accept a position as sales agent, with the General Electric Company, at their Atlanta, Ga. office.

Mr. A. Mullhaupt, Jr., formerly a student at the Pennsylvania State College, has entered in the fourth year at the Massachusetts Institute of Technology, and is residing at Technology Chambers, Boston.

Mr. A. W. K. Billings has reopened his office as consulting engineer at Havana, Cuba, having recently completed the construction of the tramway system and extension of lighting system in Santiago de Cuba.

Mr. Charles J. Spencer, of Baltimore, having successfully passed the civil service examination held in Baltimore in April, has been appointed assistant examiner in the patent office at Washington, D. C.

Mr. Leo H. Newman, until lately stationed at Roxbury, Mass., U. S. Signal Corps, has received orders to proceed to Fort Stevens, Oregon, to take up work in connection with fire control installations.

Mr. C. L. Morgan has left the Simplex Electric Company, of Boston, to affiliate himself with the Chicago branch of the Studebaker Automobile Company, particularly in connection with commercial vehicles.

Mr. H. H. Heaton, of the Missouri River Power Company, Helena, Montana, has been transferred from their Hauser Lake generating station to the operating department at the Anaconda, Montana, station.

Mr. John H. Woolliscroft, formerly with the Sandycroft Foundry Company, of Chester, England, has associated himself with H. T. Boothroyd, Hyslop & Company, electrical engineers, of Liverpool, as general manager.

Mr. W. L. Alston, lately in the commercial department at the Schenectady works of the General Electric Company, has been transferred to their Charleston, W. Va. office, where he will be actively engaged in commercial work.

After four years' experience with the New York Transportation Company, Mr. Charles M. Marsh has accepted the position of mechanical superintendent with the Terminal Taxicab Company, of Washington, D. C.

Mr. George K. Woodworth, of Browne & Woodworth, patent attorneys, announces the removal of their offices from 31 State Street, Boston, to the new Hornblower & Weeks Building, at 60 Congress Street, Boston.

Mr. Thomas B. Morgan, formerly with the Metropolitan Railway, London, has been appointed assistant manager in the electrical department of Messrs. Harland & Wolff, shipbuilders and engineers, Belfast, Ireland.

Mr. R. A. Langworthy, of Meikleham & Dinsmore, has been transferred from New York to Seneca Falls, N. Y., where he will have charge of rebuilding the Geneva, Waterloo, Seneca Falls & Cayuga Lake Traction Company.

Mr. Frederic H. Poor has been transferred from the engineering lighting department of the General Electric Company, Schenectady, to the commercial lighting department of the New York office of the same company.

Mr. C. S. Davis, who until July 1 was connected with the engineering department of the Holtzer-Cabot Electric Company, of Brookline, Mass., is now superintendent of the Marlborough Electric Company, Marlborough, Mass.

Mr. L. W. Rosenthal, until recently with the electrical department of the N. Y. C. & H. R. R.R., will leave for Central America about November 1, on reconnoissance work in connection with a projected steam or electric railroad.

Mr. Howard F. Eaton, for several years connected with Stone & Webster of Boston, Mass., has recently been appointed acting manager of the Brockton & Plymouth Street Railway Company, with headquarters at Plymouth, Mass.

Mr. William H. Browne, of Brooklyn, formerly with the Stanley Instrument Company, at Great Barrington, Mass., has taken charge of the southern office of the Rockingham Power Company, at Rockingham, N. C., as general manager.

Mr. I. W. Phillips, who has recently been engaged in construction work, with an office at 208 Balboa Building, San Francisco, has accepted a position with the Ventanas Mining & Exploration Company, Ltd., Ventanas, Durange Mexico.

Mr. T. C. James has resigned his position with the Canadian Iron & Foundry Company, Fort William, Ont., where he had charge of electrical construction, and accepted a position on the staff of the electrical engineer for the city of Toronto, Ont.

Dr. C. C. Garrard has resigned his position as manager of the transformer and instrument department of Messrs. Ferranti, Ltd., to take the post of manager of the switch department of the General Electric Company, Ltd., of Manchester, England.

Mr. W. H. Miller recently resigned his position with the power and mining engineering department, General Electric Company, Schenectady, and accepted the position of electrical engineer of the Bausch & Lomb Optical Company, Rochester, N. Y.

Mr. Edward A. Bessey, who has been connected with the Pittsfield works of the General Electric Company, formerly the Stanley Electric Manufacturing Company, has left Pittsfield and is now with the Denver Gas & Electric Company, Denver, Colo.

Dr. S. N. Taylor, who formerly had charge of the electrical engineering department at the University of Pittsburgh, has severed his connection with that institution and accepted the professorship of electrical engineering at the University of Cincinnati.

Mr. L. B. Marks, formerly at 220 Broadway, New York, and Mr. J. E. Woodwell, until recently engineer in the U. S. Government service, at Washington, have associated and opened offices in the Terminal Building, 41st Street and Park Avenue, New York.

Mr. J. G. Ross, who has just returned from a visit to England, is now engaged in consulting work relating to the design and intallation of various types of electrical machinery, and also making a specialty of the design and building of tools for electric railroad shops.

Mr. J. M. Robertson has severed his connection with the Montreal Light, Heat & Power Company, of Montreal, Canada, to enter the field of consulting engineering, under the firm name of J. M. Robertson, Ltd., with offices in the Board of Trade Building, Montreal.

Mr. Allen B. Field, for four years connected with the Bullock Electric Mfg. Co. and the electrical department of Allis Chalmers Company, in charge of their alternating-current work, excepting transformers, has severed his connection with the Allis Chalmers interests.

Mr. C. E. Fairbanks, formerly division equipment engineer for the New York & New Jersey Telephone Company, has resigned to become chief engineer of power, heating and electricity for the Gorham Manufacturing Company, with headquarters at Providence, R. I.

Mr. W. H. Tapley, until recently general manager of the Walker Electric Company, Philadelphia, has been elected secretary treasurer of the American Association of Electric Motor Manufacturers, with offices in the United Engineering Society Building, New York City.

Mr. J. S. Codman, illuminating engineer, has recently been appointed manager of the Boston office of the Holophane Company. Mr. Codman had for many years represented the Holophane Company as manager of the firm of J. S. Codman & Company, Manufacturers' Agents.

Mr. Irving W. Edwards is leaving the Westinghouse, Church, Kerr & Company, New York, to take a position as electrician in charge of the wireless telegraphy equipment to be used in Frederic Thompson's new play, " Via Wireless," of which Mr. Edwards is part author.

Mr. David Hall, for six years assistant chief engineer of the Bullock Electric Mfg. Co., and assistant chief engineer of the electrical department of Allis Chalmers Company, in charge of their direct-current work, has severed his connection with the Allis Chalmers interests.

Mr. W. A. Lynn has resigned his position as electrical engineer and purchasing agent to the San Jose and Santa Clara County Railroad Company to accept the appointment of expert electrical aide in the department of construction and repair, navy yard, Mare Island, Cal.

Mr. Henry G. Howard formerly foreman at the Necaxa power house of the Mexican Light & Power Company, has resigned his position to take up special studies at the University of California early next year. Temporarily he is with the California Gas & Electric Corporation at Oakland, Cal.

Mr. H. P. James, until lately electrical engineer of the Bryant Electric Company, Bridgeport, Conn., is now with the Cutler-Hammer Manufacturing Company, of Milwaukee, Wis., as sales manager of the new line of push button specialties which they have recently placed on the market.

Mr. C. A. Berry, who for the past nine years has been connected with the telephone engineering and switchboard installation departments of the Western Electric Company, New York, has been appointed superintendent of switchboard installation for the same company, at Hawthorne, Ill.

Mr. Clifton R. Hayes, for the past six years electrical engineer and superintendent of power and machinery, Ludlow Manufacturing Associates, Ludlow, Mass., has assumed the duties of superintendent of the electrical department of the Fitchburg Gas & Electric Light Company, Fitchburg, Mass.

Mr. Robert N. Davidson has returned from Bellevue, Idaho, where he had charge of a hydroelectric plant installed by Chas. C. Moore & Company, engineers for the Idaho Consolidated Mines Company, and is at present erecting engineer for various engineering contractors in Salt Lake City.

Mr. Henry N. Nold has severed his connection as electrical engineer with the Berlin Machine Works of Beloit, Wis., and Hamilton, Ont., and has opened an office in the Provident and Loan Building, Hamilton, Ont., where he will do a general consulting business in electrical and mechanical engineering.

Mr. Parker H. Kemble has resigned the presidency and general managership of the Northern Connecticut Light and Power Company of Windsor Locks, Conn., to take charge of the commercial development of some new processes for Burdette Loomis, of Hartford, Conn., the inventor of the Loomis-Pettibone Gas Producer.

Mr. R. E. Van Atta has withdrawn from the engineering department of the Kansas City Southern Railway Company, at Kansas City, and become associated with Mr. G. D. Sturtevant, western representative for the Arctic Ice Machine Company of Canton, Ohio, with headquarters at 708 Victor Building, Kansas City, Mo.

Mr. A. N. Cope, of Columbus, Ohio, where he was in charge of the electrical department of the Columbus Public Service Company, has been elected general superintendent of the Springfield Light, Heat & Power Company, Springfield, Ohio. Mr. Cope will have entire charge and management of the company's properties at Springfield.

Mr. B. A. Behrend, for almost ten years chief engineer of the Bullock Electric Mfg. Co., and for five years chief engineer of the electrical department of Allis Chalmers Company, the designer of the electrical machinery known as the " Bullock " and " Allis Chalmers " apparatus, has severed his connection with the Allis Chalmers interests.

Mr. Philander Betts, who for some years has been the advisory engineer for the contract department of the Potomac Electric Power Company, has resigned his position and has opened offices in the Metropolitan Bank Building, Washington, D. C., for the general practice of consulting engineering. Mr. Betts is the chairman of the Washington Section.

Mr. H. M. Gassman, for the past eight years associated with the Crocker-Wheeler Company, has accepted a position as electrical engineer for the Tennessee Coal, Iron & Railroad Company, Birmingham, Ala., and has already assumed his new duties. He will have charge of all the electrical developments of the properties of the company.

Messrs. Gerard B. Werner and **Robert Josephi** have organized an engineering and contracting business, under the firm name of The Engineering Service Company, with offices at 90 West Street, New York. They will engage in a general electrical engineering and contracting business, in the equipment of industrial power and other plants.

Mr. C. W. Jones, for the past two years assistant engineer in charge of field construction for the N. Y., N. H. & H. R.R., Company in the electrification of the New York division, has, upon completion of the construction work, removed his office to Providence, R. I., where he will take up the field work on the extension of the Providence, Warren and Bristol trolley line.

Mr. Monroe G. Haight, formerly assistant to electrical engineer of the Westchester Lighting Company at Mt. Vernon, N. Y., has recently assumed the position of electrical engineer with the Boston & Idaho Gold Dredging Company, who are operating in Idaho, building a dam and generating station on the Payette River to supply electrical power along its transmission line.

Mr. Horatio A. Foster, for the past year and a half in charge of the Baltimore office of L. B. Stillwell as resident engineer, has resigned and become connected with the valuation department of the Public Service Commission, First District, New York. This department is under the direction of Mr. Bion J. Arnold, of Chicago, and is evaluating the surface car lines of Manhattan and the Bronx.

November Meeting of the A. S. M. E.

The November meeting of The American Society of Mechanical Engineers will be held in the Engineers' Building, 33 West Thirty-ninth street, on Tuesday evening, November 10. Mr. Franklin Phillips, president of the Hewes & Phillips Iron Works, Newark, N. J., will make an address, illustrated by lantern slides, on " The High Powered Rifle and its Ammunition—Instruments of Precision."

December Meeting A. S. M. E.

In view of the remarkable attainments in the development of flying machines and airships during the past few months, the American Society of Mechanical Engineers have arranged for an exhaustive paper on aeronautics by Major George O. Squier, of the Signal Corps, U.S.A., Washington, D. C., to be read at the annual meeting in New York, December 1-4. This will be the first comprehensive treatment of the subject by an American engineering society and discussion of unusual interest will be contributed both by engineers and scientists.

An evening lecture upon aeronautics will also be given by Lieut. Frank P. Lahm of the Signal Corps, illustrated with lantern views and moving pictures of the recent trials at Fort Myer.

Obituary

Albert Morrison Bullard, of the Western Electric Company, New York, died on September 19, 1908, at Liberty, New York. Mr. Bullard, son of Gardner W. and Fanny K. (Field) Bullard, was born January 6, 1868, at Boston, Mass., and was the youngest brother of the composer, Frederic Field Bullard, who died in June 1904. He was elected an Associate of the Institute on March 27, 1903. His preliminary education was received in Boston grammar and high schools, and in 1885 he entered the Massachusetts Institute of Technology. Leaving that institution in 1888 he entered the employ of the Thomson-Houston Company, Lynn, Mass. From 1891 to 1903 he was engaged in special work on electrical welding, mechanical devices of telephony, and automatic telephones, for various companies. In 1903 he entered the employ of the Western Electric Company, New York, and until the time of his death was directly in charge of the installation of automatic plants at Queens and other points, and other larger problems of similar nature. In 1904 he married Marion Rorty, sister of Malcolm Rorty, of the Pittsburg Telephone Company. Mr. Bullard was artistic in temperament, refined in his tastes, a congenial co-worker, firm in friendships, kindly and considerate toward all. In addition to his natural mechanical talents he was a lover of music, and was a performer of ability. Both parents and a sister survive him.

Dr. Frederic A. C. Perrine, a prominent Member of the Institute, died at his home in Plainfield, New Jersey, Wednesday morning, October 21, 1908, of Bright's disease, after an illness of several months. Dr. Perrine was born at Manalapan, New Jersey, August 25, 1862, and was the son of James A. and Rebecca (Combs) Perrine. He was graduated from Princeton College in 1883, with the degree of A.B. Later he received the degree of D.Sc. from the same institution. On September 16, 1890, he was elected an Associate of the American Institute of Electrical Engineers, and on December 16, 1890, was transferred to the grade of Member. He was a Manager, and a member of the Council of the Institute, from 1898 to 1900. On June 28, 1893, he married Margaret J. Roebling. After several years of practical engineering, Dr. Perrine accepted the appointment of professor of electrical engineering at Leland Stanford, Jr., University, California. From 1898 to 1900 he was chief engineer of the Standard Electric Company, of California. Resigning that position in 1900, he became president of the Stanley Electric Manufacturing Company, Pittsfield, Mass. In the latter part of 1904 he entered the consulting engineering field, with offices at 49 Wall Street, New York. Later he removed to 60 Wall Street, where he was established until the time of his death. Dr. Perrine was widely known to the engineering profession by his contributions on electrical engineering topics, and through his activity in Institute affairs. His wife, two daughters, Margaret and Anne Perrine, and one son, John, survive him.

Library Accessions

SEPTEMBER 1 TO 31, 1908

The following donations have been made to the library since the last acknowledgement:

American Institute of Electrical Engineers:

Transactions, Vol. 26, 9x5¾ in. New York, 1908.

Electric Journal:

Railway Signalling. Written by a staff of Expert Signal Engineers. 108 p. 9x6¼ in. Pittsburgh, Electric Journal, 1908. Price 75 cents.

McGraw Publishing Company:

BERG, E. J. *Electrical Energy.* 184 p. 9x6¼ in. New York, McGraw Publishing Company, 1908. Price $2.50 net.

DEINHARDT, K., and SCHLOMANN, A., Editors. Technical Illustrated Dictionary in Six Languages—English, German, French, Russian, Italian and Spanish. Vol. 2. *Electrical Engineering.* Compiled by Chas. Kinzbrunner. 2112 p. 7x4¼ in. New York McGraw Publishing Company, 1908. Price $7.00 net.

SCOTT, RALPH. *Automatic Block Signals and Signal Circuits.* 243 p. 9x6¼ in. New York, McGraw Publishing Company. Price $2.50 net.

Standard Handbook for Electrical Engineers. Edition 2. 6¾x4¼ in. New York, McGraw Publishing Company, 1908. Price $4.00 net.

G. Marconi:

MARCONI, G. *Lectures on Wireless Telegraphy* delivered before the Royal Institution of Great Britain, March 13, 1908. 24 p. 8 vo.

C. L. de Muralt:

Electric Trunk Line Age, Nos. 1-10 1908. 10x7½ in. New York, 1908.

Prof. C. P. Steinmetz:

STEINMETZ, C. P. *The Future of Electricity.* Lecture delivered to the Students of the New York Electrical Trade School. 21 p. 8½x5 in. n.d.

TRADE CATALOGUES

THE COLLINS WIRELESS TELEPHONE COMPANY, 54 Clinton St., Newark, N. J.

CROCKER WHEELER COMPANY, Ampere, N. J. Polyphase Induction Motors (Bulletin No. 105), June 1908.

THE EMERSON ELECTRIC MFG. COMPANY, New York City. Single Phase Induction Motors (Bulletin Nos. 3128, 3129, 3130, 3131).

Family Sewing Machine Motors (Bulletin No. 3906).

Officers and Board of Directors, 1908-1909

PRESIDENT

LOUIS A. FERGUSON, Chicago, Ill.

JUNIOR PAST-PRESIDENTS.

SAMUEL SHELDON, Brooklyn, N. Y.
HENRY GORDON STOTT, New York, N. Y.

VICE-PRESIDENTS

JAMES G. WHITE, New York, N. Y.
JOHN J. CARTY, New York, N. Y.
W. C. L. EGLIN, Philadelphia, Pa.

CUMMINGS C. CHESNEY, Pittsfield, Mass.
BANCROFT GHERARDI, New York, N. Y.
CALVERT TOWNLEY, New Haven, Conn.

MANAGERS

A. M. SCHOEN, Atlanta, Ga.
PAUL M. LINCOLN, Pittsburgh, Pa.
PAUL SPENCER, Philadelphia, Pa.
WILLIAM S. MURRAY, New Haven, Conn.

MORGAN BROOKS, Urbana, Ill.
HAROLD W. BUCK, New York, N. Y.
PERCY H. THOMAS, Montclair, N. J.
BENJAMIN G. LAMME, Pittsburgh, Pa.

DAVID B. RUSHMORE, Schenectady, N. Y.
W. G. CARLTON, New York N. Y.
CHARLES W. STONE, Schenectady, N. Y.
H. E. CLIFFORD, Boston, Mass.

TREASURER

GEORGE A. HAMILTON, New York, N. Y.

SECRETARY

RALPH W. POPE, New York, N. Y.

PAST-PRESIDENTS

T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
ALEX. GRAHAM BELL, 1891-2.
FRANK J. SPRAGUE, 1892-3.
EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS B. CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1901.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, JR., 1904.5.
SCHUYLER S. WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY GORDON STOTT, 1907-8.

ASSISTANT SECRETARY

FREDERICK L. HUTCHINSON,
33 West 39th Street, New York, N. Y.

GENERAL COUNSEL

PARKER and AARON,
52 Broadway, New York N. Y.

Standing Committees

EXECUTIVE COMMITTEE.

LOUIS A. FERGUSON, Chairman.
139 Adams Street, Chicago, Ill.
JOHN J. CARTY, New York.
C. C. CHESNEY, Pittsfield, Mass.
WM. C. L. EGLIN, Philadelphia, Pa.
GEORGE A. HAMILTON, New York.
RALPH W. POPE, New York.
CALVERT TOWNLEY, New Haven, Conn.

FINANCE COMMITTEE.

CALVERT TOWNLEY, Chairman.
The Connecticut Co., New Haven, Conn.
HAROLD W. BUCK, New York.
BANCROFT GHERARDI, New York.

LIBRARY COMMITTEE.

EDWARD CALDWELL, Chairman.
239 West 39th Street, New York.
W. G. CARLTON, New York.
H. E. CLIFFORD, Boston, Mass.
MAX LOEWENTHAL, New York.
PHILIP TORCHIO, New York.

MEETINGS AND PAPERS COMMITTEE.

A. H. ARMSTRONG, Chairman.
G. E. Co., Schenectady, N. Y.
BION J. ARNOLD, Chicago, Ill.
JOHN J. CARTY, New York.
RALPH D. MERSHON, New York.
H. H. NORRIS, Ithaca, N. Y.
C. E. SKINNER, Pittsburgh, Pa.

EDITING COMMITTEE.

GEORGE F. SEVER, Chairman.
Columbia University, New York.
A. H. ARMSTRONG, Schenectady, N. Y.
SAMUEL SHELDON, Brooklyn, New York.

BOARD OF EXAMINERS.

HAROLD W. BUCK, Chairman.
49 Wall Street, New York.
H. H. BARNES, JR., New York.
MAURICE COSTER, New York.
WM. C. L. EGLIN, Philadelphia, Pa.
D. C. JACKSON, Boston, Mass.

SECTIONS COMMITTEE.

PAUL SPENCER, Chairman.
Broad and Arch Streets, Philadelphia, Pa.
H. R. KING, Chicago, Ill.
PAUL M. LINCOLN, Pittsburgh, Pa.
H. H. NORRIS, Ithaca, N. Y.
D. B. RUSHMORE, Schenectady, N. Y.

STANDARDS COMMITTEE.

SAMUEL SHELDON, Chairman.
Polytechnic Institute, Brooklyn, N. Y.
B. A. BEHREND, Milwaukee, Wis.
GANO DUNN, Ampere, N. J.
A. E. KENNELLY, Boston, Mass.
J. W. LIEB, JR., New York.
CHARLES F. SCOTT, Pittsburgh, Pa.
CLAYTON H. SHARP, New York.
C. P. STEINMETZ, Schenectady, N. Y.
S. W. STRATTON, Washington, D. C.

CODE COMMITTEE.

F. A. C. PERRINE, Chairman.
60 Wall Street, New York.
C. W. STONE, Vice-chairman,
G. E. Co., Schenectady, N. Y.
W. H. BLOOD, JR., Boston, Mass.
WASHINGTON DEVEREUX, Philadelphia,
JOSEPH C. FORSYTH, New York.
H. B. GEAR, Chicago, Ill.
FARLEY OSGOOD, Newark, N. J.
H. S. WARREN, New York.
ARTHUR WILLIAMS, St. Louis, Mo.

LAW COMMITTEE.

H. G. STOTT, Chairman.
600 West 59th Street, New York.
A. E. KENNELLY, Boston, Mass.
J. W. LIEB, JR., New York.
CHARLES F. SCOTT, Pittsburgh, Pa.
SAMUEL SHELDON, Brooklyn, N. Y.

Special Committees

RAILWAY COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
BION J. ARNOLD, Chairman,
181 La Salle Street, Chicago, Ill.
E. H. ANDERSON, Schenectady, N. Y.
GEORGE GIBBS, New York.
H. ST. CLAIR PUTNAM, New York.
N. W. STORER, Pittsburgh, Pa.

EDUCATIONAL COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
HENRY H. NORRIS, Chairman.
Cornell University, Ithaca, N. Y.
H. E. CLIFFORD, Boston, Mass.
GANO DUNN, Ampere, N. J.
G. A. HOADLEY, Swarthmore, Pa.
C. O. MAILLOUX, New York.
CHARLES F. SCOTT, Pittsburgh, Pa.
CHARLES P. STEINMETZ, Schenectady, N.Y.

HIGH-TENSION TRANSMISSION COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
RALPH D. MERSHON, Chairman.
60 Wall Street, New York.
C. C. CHESNEY, Pittsfield, Mass.
PAUL M. LINCOLN, Pittsburgh, Pa.
W. S. MOODY, Schenectady, N. Y.
W. N. RYERSON, Niagara Falls, N. Y.

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

H. G. STOTT, Chairman.
600 West 59th Street, New York.
W. L. ABBOTT, Chicago, Ill.
W. H. BLOOD, JR., Boston, Mass.
JOHN H. FINNEY, Washington, D. C.
P. G. GOSSLER, New York.
F. A. C. PERRINE, New York.
CHARLES H. PORTER, Boston, Mass.

COMMITTEE ON INDUSTRIAL POWER.

D. B. RUSHMORE, Chairman.
G. E. Co., Schenectady, N. Y.
CHARLES DAY, Philadelphia, Pa.
GANO DUNN, Ampere, N. J.
R. S. FEICHT, Pittsburgh, Pa.
E. W. LLOYD, Chicago, Ill.
B. R. SHOVER, Gary, Ind.
R. B. WILLIAMSON, Milwaukee, Wis.

COMMITTEE ON INCREASE OF MEMBERSHIP.

C. W. STONE, Chairman.
G. E. Co., Schenectady, N. Y.
A. W. BERRESFORD, Milwaukee, Wis.
HENRY L. DOHERTY, New York.
GANO DUNN, Ampere, N. J.
BANCROFT GHERARDI, New York.
F. L. HUTCHINSON, New York.
H. R. KING, Chicago, Ill.
S. M. KINTNER, Pittsburgh, Pa.
H. L. SMITH, Schenectady, N. Y.
SEVERN D. SPRONG, New York.
W. L. WATERS, Pittsburgh, Pa.
P. B. WOODWORTH, Chicago, Ill.

COMMITTEE ON INTERMEDIATE GRADE OF MEMBERSHIP.

CHAS. F. SCOTT, Chairman.
W. E. & M. Co., Pittsburgh, Pa.
K. L. AITKEN, Toronto, Canada.
WILLIAM McCLELLAN, New York.
GEORGE F. SEVER, New York.
PAUL SPENCER, Philadelphia, Pa.

EDISON MEDAL COMMITTEE.

CHARLES L. CLARKE, Chairman.
120 Broadway, New York.
HENRY L. DOHERTY.
HENRY G. STOTT.
GEO. A. HAMILTON.

T. C. MARTIN.
WM. HAND BROWNE, JR.

JOHN W. HOWELL.
CHARLES F. SCOTT.
SAMUEL REBER.

GANO DUNN.
CHARLES A. TERRY.
W. S. BARSTOW.

CHARLES E. LUCKE.
DUGALD C. JACKSON.
C. A. ADAMS.

REPRESENTATIVES ON BOARD OF AWARD OF THE JOHN FRITZ MEDAL.

JOHN W. LIEB, JR.
SCHUYLER SKAATS WHEELER.
SAMUEL SHELDON.
HENRY G. STOTT.

REPRESENTATIVES, BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

CHARLES F. SCOTT, Pittsburgh, Pa.
JOHN W. LIEB, JR., New York.
SAMUEL SHELDON, Brooklyn, N. Y.

REPRESENTATIVES ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SAMUEL SHELDON, Brooklyn, N. Y.
PERCY H. THOMAS, New York.

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

United States National Committee.

ELIHU THOMSON, President, Lynn, Mass.
CHARLES F. SCOTT, 1st Vice-president.
SAMUEL SHELDON, 2d Vice-president.
ARTHUR E. KENNELLY, Secretary,
Harvard University, Cambridge, Mass.
BION J. ARNOLD.
B. A. BEHREND.
A. W. BERRESFORD.
JOHN J. CARTY.
W. C. L. EGLIN.
CARL HERING.
JOHN W. HOWELL.
DUGALD C. JACKSON.
FRANCIS W. JONES.
BENJAMIN G. LAMME.
W. A. LAYMAN.
JOHN W. LIEB, JR.
CLAYTON H. SHARP.
CHARLES P. STEINMETZ.
LEWIS B. STILLWELL.
HENRY G. STOTT.
SAMUEL W. STRATTON.

Local Honorary Secretaries

JAMES S. FITZMAURICE,
210 George St., Sydney, N. S. W.

H. F. PARSHALL,
Salisbury House, London Wall E. C., London.

ROBERT B. OWENS,
McGill University, Montreal, P. Q.

WILLIAM B. HALE,
Cadena 10, City of Mexico.

W. G. T. GOODMAN,
Adelaide, South Australia.

ROBERT J. SCOTT,
Christ Church, New Zealand.

HENRY GRAFTIO,
St. Petersburg, Russia.

Sections and Branches—Directory.

Sections	Organization authorized by Board of Directors	Chairman	Secretary
Atlanta	Jan. 19, '04	J. H. Finney	G. J. Yundt, Southern Bell Tel. Co., Atlanta, Ga.
Baltimore	Dec. 16, '04	J. B. Whitehead	C. G. Edwards, City Hall, Baltimore, Md.
Boston	Feb. 13, '03	A. E. Kennelly	A. L. Pearson, 93 Federal St., Boston, Mass.
Chicago	1893	H. R. King	J. G. Wray, 203 Washington St., Chicago, Ill.
Cincinnati	Dec. 17, '02	A. G. Wessling	
Cleveland	Sept. 27, '07	C. W. Ricker	F. M. Hibben, 1549 Winton Ave., Cleveland, O.
Columbus	Dec. 20, '03	R. J. Feather	H. L. Bachman, 1070 E. Fulton St., Columbus, O.
Fort Wayne	Aug. 14, '08	E. A. Wagner	J. V. Hunter, 506 W. Jefferson St., Ft. Wayne, Ind.
Ithaca	Oct. 15, '02	E. L. Nichols	H. H. Norris, Cornell Univ., Ithaca, N. Y.
Los Angeles	May 19, '08	C. W. Koiner	J. E. MacDonald, 444 P. E. Bldg., Los Angeles, Cal.
Mexico	Dec. 13, '07	R. F. Hayward	F. D. Nims, Mex. Lt. & Pr. Co., Mexico, Mex.
Minnesota	Apr. 7, '02	E. H. Scofield	A. L. Abbott, 185 E. 4th St., St. Paul, Minn.
Norfolk	Mar. 13, '08	D. G. Stanbrough	R. R. Grant, P. O. Box 254, Norfolk, Va.
Philadelphia	Feb. 18, '03	Paul Spencer	H. F. Sanville, 1708 Sansom St., Phila., Pa.
Pittsburg	Oct. 13, '02	W. Edgar Reed	B. P. Rowe, 911 Ramsey Ave., Wilkinsburg, Pa.
Pittsfield	Mar. 25, '04	W. A. Hall	H. W. Tobey, General Electric Co., Pittsfield, Mass.
San Francisco	Dec. 23, '04	A. M. Hunt,	G. R. Murphy, 2699 Union St., San Francisco, Cal.
Schenectady	Jan. 26, '03	E. J. Berg	M. O. Troy, G. E. Co., Schenectady, N. Y.
Seattle	Jan. 19, '04	J. H. Harisberger	Geo. H. Moore, 816 Terry Ave., Seattle, Wash.
St. Louis	Jan. 14, '03	A. S. Langsdorf	H. I. Finch, 5228 Kensington Ave., St. Louis, Mo.
Toledo	June 3, '07	C. R. McKay	Geo. E. Kirk, 1614 The Nichols, Toledo, O.
Toronto	Sept. 30, '03	W. A. Bucke	W. G. Chace, 124 Confed. Life Bldg., Toronto, Can.
Urbana	Nov. 25, '02	E. B. Paine	E. J. Wenger, 911 W. California St., Urbana, Ill.
Washington, D. C.	Apr. 9, '03	Philander Betts	H. C. Eddy, 806 Westory Building, Washington, D. C.

Sections and Branches—Directory.

Branches	Organization authorized by Board of Directors	Chairman	Secretary
Arkansas, Univ. of....	Mar. 25, '04	M. F. Thompson	C. R. Rhodes, Univ. of Ark., Fayetteville, Ark.
Armour Institute......	Feb. 26, '04	T. W. Simpson	J. E. Snow, Armour Inst. Tech., Chicago, Ill.
Cincinnati. Univ. of...	Apr. 10, '08	C. R. Wylie	C. A. Winder, 1332 Lincoln Ave., Cincinnati, O.
Colorado, Univ. of.....	Dec. 16, '04	H. H. Watters	L. D. Jones, Univ. of Colorado, Boulder, Colo.
Iowa State College....	Apr. 15, '03	F. A. Fish	Adolph Shane, Iowa State College, Ames, Ia.
Kansas State Agr. Col..	Jan. 10, '08	W. L. Enfield	W. C. Lane, Kan. State Agr. Col., Manhattan, Kan.
Kansas, Univ. of......	Mar. 18, '08	Martin E. Rice	H. P. Broderson, Univ. of Kansas, Lawrence, Kan.
Lehigh University.....	Oct. 15, '02	H. O. Stephens	J. A. Clarke, Jr., Lehigh Univ., Bethlehem, Pa.
Lewis Institute........	Nov. 8, '07	W. H. Hayes	P. B. Woodworth, Lewis Institute, Chicago, Ill.
Maine, Univ. of.......	Dec. 26, '06		Gustav Wittig, Univ. of Maine, Orono, Me.
Michigan, Univ. of....	Mar. 25, '04	C. M. Davis	H. F. Baxter, 556 S. State St., Ann Arbor, Mich.
Missouri, Univ. of.....	Jan. 10, '03	H. B. Shaw	H. D. Carpenter, Univ. of Missouri, Columbia, Mo.
Montana Agr. Col.....	May 21, '07	B. S. Hind	J. A. Thaler, Montana Agr. Col., Bozeman, Mont.
Nebraska, Univ. of....	Apr. 10, '08	Geo. H. Morse	L. E. Hurtz, Lincoln Tel. Co., Lincoln, Neb.
Ohio State Univ......	Dec. 20, '02	F. W. Funk	F. C. Caldwell, Ohio State Univ., Columbus O.
Oregon State Agr. Col..	Mar. 24, '08	E. V. Hawley	E. C. Wiggen, Oregon St. Agr. Col., Corvallis, Ore.
Penn. State College....	Dec. 20, '02	D. R. Simpson	C. D. Preston, Penn. State College, Pa.
Purdue Univ..........	Jan. 26, '03	J. W. Esterline	H. T. Plumb, Purdue Univ., Lafayette, Ind.
Stanford Univ........	Dec. 13, '07	W. C. North	A. J. Gowan, Stanford Univ., California.
Syracuse Univ........	Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse Univ., Syracuse, N. Y.
Texas, Univ. of.......	Feb. 14, '08	A. C. Scott	B. E. Kenyon, Univ. of Texas, Austin, Tex.
Wash. State Col. of...	Dec. 13, '07	H. V. Carpenter	M. K. Akers, State Col. of Wash., Pullman, Wash.
Washington Univ.....	Feb. 26, '04	C. M. Duncan	H. F. Thomson, 5011 Washington Ave., St. Louis, Mo.
Wisconsin, Univ. of...	Oct. 15, '02	O. H. Ensign	J. W. Shuster, Univ. of Wisconsin, Madison, Wis.
Worcester Poly. Inst..	Mar. 25, '04	F. A. Spencer	W. D. Stearns Worcester Poly. Inst., Worcester, Mass.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly at 33 W. 39th St., New York,
under the supervision of

THE EDITING COMMITTEE

GEORGE F. SEVER, Chairman
A. H. ARMSTRONG SAMUEL SHELDON

GEORGE A. WARDLAW, Editor

Subscription. $10.00 per year for all countries to which the bulk rate of postage applies.
All other countries $12.00 per year.
Single copy $1.00.
Subscriptions must begin with January issue.

Advertisements accepted from reputable concerns at the following net rates:

Space	**Less than half year** per issue	**Half year** per issue	**One year** per issue
1 page	$50.00	$44.00	$40.00
½ page	30.00	25.00	22.00

Additional charges for Preferred Positions.

Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month.

Vol. XXVII **December, 1908** No. 12

December Meeting A. I. E. E.

THE two hundred and thirty-second meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West Thirty-ninth Street, New York, on Friday, December 11, 1908, at eight o'clock p.m. A paper entitled, "The Log of the New Haven Electrification," will be presented by Mr. W. S. Murray, electrical engineer of the New York, New Haven and Hartford Railroad Company. The paper is printed in this issue of the PROCEEDINGS, pages 1609-1660. It contains much interesting and valuable data relating to the experience gained between April 1, 1905, and November 1, 1908, in equipping and operating the New York, New Haven and Hartford Railroad between New York and Stamford, Conn., with 11,000-volt, 25-cycle, single-phase alternating current. In advocating the use of high-voltage, low-cycle, single-phase alternating current for trunk line traction, Mr. Murray says:

> The object of this paper is to bring the actual operation of the New Haven single-phase electrification as closely as possible to those who are truly interested in its merits and faults.
>
> * * * * * * * *
>
> To those who may be interested in my conclusion in regard to the New Haven Railroad electrification, I can simply say that if I were in favor of its use three years ago, that now, standing on the more stable ground of experience particularly in regard to the department of faults, I am doubly in favor of it to-day. I shall, of course, be interested in those who share this opinion after reading this paper, * * * and * * * I shall be equally interested in those who honestly disagree with this opinion.
>
> * * * * * * * *
>
> The New Haven system provides that the volt manufactured in and leaving the doors of the power house, is the same physical volt that knocks at the doors of the locomotives. Thus the line is the single link that unites the power house and the locomotives. All such adjuncts as step-down transformers, synchronous converters, storage-batteries, and low-voltage distributing systems with their necessary attendant complement of help is dispensed with. The Cos Cob power house has the usual number of men for a station of its output, and the locomotives are operated by the electric locomotive engineer with the customary assistant present for emergency. This crew holds good for single- or double-unit trains. An emergency repair train is the guardian of the line, attending to all matters pertaining to its repair and maintenance. Including the night and day crews of the emergency train, the number of men employed to maintain the distribution system is nineteen. This covers about 100 miles of single track, including yards.
>
> * * * * * * * *
>
> The paper has been written with the intent to lay before the members of the American Institute of Electrical Engineers a practical picture of the New Haven single-phase electrification describing the first suit of clothes it wore and what it is wearing now. He [the author] is conscious of the innumerable little points of real interest that time and opportunity have not permitted him to insert here, but he trusts to the discussion to bring them out.

Minutes of November Meeting of the Institute

The two hundred and thirty-first regular meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West Thirty-ninth street, New York, Friday, November 13, 1908. President Ferguson called the meeting to order at 8:15 p.m.

The secretary announced that at the meeting of the Board of Directors held during the afternoon there were 59 Associates elected, as follows:

Abbott, Walter Hazelton, Roberts & Abbott Co., Schofield Bldg., res.; 11123 Euclid Ave., Cleveland, Ohio.

Acheson, Albert Robert, Asst. Prof. of Mechanical Engineering, Syracuse University, Syracuse, N. Y.

Barrow, Charles J., Electrical Engineer, General Electric Co.; res., 206 South Ave., Schenectady, N. Y.

Bass, Joseph E., Chief Operator, Electric Power Dept., Los Angeles Ry. Co. Los Angeles, Cal.

Beckwith, J. W., Superintendent, Northern Electric Company, Newport, Washington.

Bell, Edwin Archelaus, Electrician, Stroudsburg, Pa.

Bollschweiler, Charles Frederick, Dist. Supt. of Construction, Pacific Tel. & Tel. Company, 1320 South Hope St., Los Angeles, Cal.

Bowker, William Rushton, Professor of Physics and Elec. Engr., Univ. of Southern California, Los Angeles, Cal.

Calangis, Arthur A., Night Inside-man, N. Y. & N. J. Telephone Co.; res., 158 E. 92d St., New York City.

Cannon, Fred Kendric, Salesman, Stromberg. Carlson Tel. Mfg. Co.; res., 7340 Stewart Ave., Chicago, Ill.

Carter, Charles Hardeson, Vice-President, Pacific Electrical Works, 330 South Los Angeles St., Los Angeles, Cal.

Cisneros, Anibal, Commissioner, Bureau of Public Utilities of Argentine Republic, S. A.

Collbohm, Max. H., Electrical Engineer, with Prof. Daniel W. Mead; res., 613 N. Francis St., Madison, Wis.

Cook, Edgar William, Electrician, Pacific Electric Railway Company, Los Angeles, Cal.

Cumming, Ford J., Superintendent, City of Edmonton Telephone Dept.; res., Edmonton, Alberta, Can.

Dyer, Isaac Tillman, Supt. Telegraph & Telephones, S. P. L. A. & S. L. R.R. 559 P. E. Bldg., Los Angeles, Cal.

Eastwood, Harry Wilder, Sales Representative, The Electric Controller & Mfg. Co., Cleveland, O.

Edwards, Joseph Paulding, Electrical and Mechanical Engineer, Northern Electric Railway Co., Chico, Cal.

Eoff, Beverly McCrae, Asst. Editor, *G. E. Review*, General Electric Co., Schenectady, N. Y.

Farmer, Frank Harvey, Construction Engineer, Canadian Westinghouse Co., Hamilton, Ont.

Feig, Paul Roy, Student; res., 442 Manhattan Ave., New York.

Finkle, Frederick Cecil, Consulting Engineer, Edison Electric Co., 230 J.W. Hellman Bldg., Los Angeles, Cal.

Fisher, Allen Harry, Generating Station Operator, The Guanajuata Power & Electric Company, Zamora, Mich., Mex.

Frank, Dr. Karl Georg, Electrical Engineer, Siemens & Halske A. G. Berlin, Ger.; Room 1559, Hudson Terminal Bldg., New York City.

Goldback, M. Gustavus, Secretary & Treasurer, Atlantic Electric Co., Inc., res., 85 Commerce St., Norfolk, Va.

Herbert, George Sidney, Engineer, Celaya Lighting & Power Co., Postal de Guadalupe, Celaya, Mexico.

Hobson, Henry Elmer, Manager, Apparatus Dept., Hobson Electric Co., Dallas, Tex.

Hyde, Edward Pechin, Associate Physicist in charge of Photometry, Bureau of Standards, Washington, D. C.

Jackson, John Grant, Engineering Dept., N. Y. Edison Co., 55 Duane St., N. Y. City; res., Bensonhurst, L. I.

JUDSON, CLARENCE B., Repairman of Electrical Apparatus, L. A. Gas & Elec. Co., res., 4957 Pasadena Ave., Los Angeles, Cal.

KERNS, RALPH W., Switchboard Operator, Missouri River Power Co.; res., 604 Maple, Anaconda, Mont.

KIMURA, KOMAKICHI, Chief Engineer, Osaka Electric Lighting Company, Osaka, Japan.

LEE, HAROLD H., General Foreman, Los Angeles Pacific Co., Sherman, California.

LOWELL, HERBERT GRANVILLE, Manager & Supt., Templeton Municipal Light Dept., East Templeton, Mass.

MACKENZIE, HOWARD ARCHIBALD, Dredging Supt., Jhelum Power Installation, Baramulla, Kashmir, India.

MACKNESS, CYRIL FRANCIS, Technical & Com. Engineer, The A. E. G. of Berlin; res., 605 Caxton House, Westminster, London, S. W., Eng.

MANAHAN, FRANK TIMOTHY, Chief Electrician, Choctaw Ry. and Ltg. Co.; res., McAlester, Okla.

MANN, RALPH BYINGTON, Chief Engineer, Nogales Electric Light, Water and Ice Co., Nogales, Ariz.

MEINIG, RUDOLPH ERNEST AUGUST, Draftsman, N. Y. Edison Co., 55 Duane St.; res., 314 E. 51st St., New York City.

MILLAR, THOMAS RUSSELL, Operator, Buffalo, Lockport & Rochester Ry.; res., 225 Main St.. Brockport, N. Y.

PERRY, J. FRANK, Engineer & Sales Manager, Allis-Chalmers Co., 623 Citizens National Bank Bldg., Los Angeles, Cal.

PHINNEY, EDWARD ALLEN, Secretary, Treasurer & Manager, Ouray Electric Power and Light Co., Ouray, Colo.

PLOWDEN, JAMES OLIVER, Electrician, Pacific Electric Ry. Co., 285 P. E. Bldg., Los Angeles, Cal.

RICHMOND, CARL ADAMS, Patent Lawyer, Sheridan & Wilkinson, Marquette Bldg., Chicago, Ill.

RILEY, GEORGE ALBERT, Inspector, L. A. Gas & Electric Co.; res., 1213 W. 5th St., Los Angeles, Cal.

ROAKE, CHESTER H., Chief Draftsman, Northern Electric Ry. Co., E. & M. E. Dept., res.; 926 Sixth St., Chico, Cal.

RUNGE, WALTER, Public Service Railway Co.; res., 130 Union St., Newark, N. J.

SEYMOUR, JOSEPH FRANKLIN, JR., Pacific Tel. & Tel. Co.; res., 3661 South Grand Ave., Los Angeles, Cal.

SPRAGUE, STARBUCK, General Manager, National Electric Equipment Co., 11 High St., Boston; res., Winthrop, Mass.

TAYLOR, ALVIN ALFRED WHEATLEY, Managing Partner, T. T. Electric Fitting & Supply Co., North Sydney, N. S. W.

TESSIER, EUGENE LOUIS, Factory Inspector, Virginia Carolina Chemical Co., Richmond, Va.

TRUMBO, ERNEST G., Chief Engineer, Las Vegas Railway and Power Co., East Las Vegas, New Mexico.

VANCE, CHAMP S., Mgr. of Operation, Los Angeles Gas & Electric Co.; res., 645 South Hill St., Los Angeles, Cal.

VAN DEVENTER, HARRY RANDOLPH, The Sumter Tel. Mfg. Co., Sumter, S. C.

WARD, HENRY JAMES, Tester, Western Electric Co., Hawthorne; res., 1980 Washington Blvd., Chicago, Ill.

WEBER, THEODORE J., Engineer, Child, Hulswit & Co.; res., 107 Auburn Ave., Grand Rapids. Mich.

WIDMER, HENRY, Engineer & Contractor, 1018 Hibernia Bldg., New Orleans, La.

WITHERELL, ALONZO T., Superintendent of Manufacturing, N. Y. and Queens Electric Light and Power Co.; res., Astoria, L. I.

YEAGER, LLOYD BRAZELTON, General Foreman of Lines, Los Angeles Ry. Co.; res., 322 W. 47th St., Los Angeles, Cal.

The secretary announced further that the revised By-Laws approved by the Board of Directors during the afternoon would go into effect and be printed and distributed at once.

Mr. W. S. Hadaway, Jr., of Pittsburg, Pa., then presented a paper entitled, "Electric Heating." The paper was discussed by Messrs. C. E. Waddell, W. N. Ryerson, W. S. Andrews, J. I. Ayer, P. M. Lincoln, H. P. Ball, M. Loewenthal, C. P. Steinmetz, and W. S. Hadaway.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before December 20, 1908.

7970 Slutz, Charles S., Los Angeles, Cal.
7971 Roffee, Barton E., Chicago, Ill.
7972 Miller, Morton, O., Utica, N. Y.
7973 Hinckley, W. G., Hartford, Conn.
7974 McKenzie, F. W., Massillon, Ohio.
7975 Brown, Charles, E., Chicago, Ill.
7976 Wischmeyer, H. W., Louisville, Ky.
7977 Whitson, Vilic D., Seymour, Ind.
7978 King, John R., Seattle, Wash.
7979 Gregson, E. J., Schenectady, N. Y.
7980 Matus, Miguel A., Jalapa, Mex.
7981 Short, Andrew J., Rome, N. Y.
7982 Vinson, A. W., San Francisco, Cal.
7983 La Rue, James M., Summit, N. J.
7984 Slocum, T. N., Aberdeen, Wash.
7985 Berger, George R., Newark, N. J.
7986 Mastick, R. W., Jr., Berkeley, Cal.
7987 Seibel, Charles W., Oak Park, Ill.
7988 Woodard, A. V., Stanford University, Cal.
7989 Rowat, F. T., Des Moines, Iowa.
7990 Harrison, Charles E., Atlanta, Ga.
7991 Richards, L. C., New Rochelle, N. Y
7992 Waters, Granville A., St. Louis, Mo.
7993 Higson, C. R., Madison, Wis.
7994 Haskell, F. E., West Lynn, Mass.
7995 Ellis, John W., Schenectady, N. Y.
7996 Moore, Leon J., Los Angeles, Cal.
7997 Hoefer, Elmer G., Laramie, Wyo.
7998 Boyles, R. G., Los Angeles, Cal.
7999 Chamberlin, Egbert C., N. Y. City.
8000 Sinclair, H. H., Los Angeles, Cal.
8001 Pease, Maurice H., El Paso, Texas.
8002 Keel, C. H., Schenectady, N. Y.
8003 Gochicoa, E. O., Temascaltepec, Mexico.
8004 Schiller, Walter R., Utica, N. Y.
8005 Lembeck, A. W., Salt Lake City, Utah.
8006 Blackwell, H. C., Davenport, Iowa
8007 Hutchings, O. H., Dayton, O.
8008 Sturrock, A. G., Aguascalientes, Mexico.
8009 Davis, E. H., Williamsport, Pa.
8010 Field, F. W., Iowa City, Ia.
8011 Fagberg, C. J., Los Angeles, Cal.
8012 Plum, Verne, Iowa City, Ia.
8013 Twiggs, J. D., Jr., Augusta, Ga.
8014 Camp, Eugene V., Urbana, Ill.
8015 Fay, Frank H., New York City.
8016 Weller, F. M., Schenectady, N. Y.
8017 McLain, R. H., Schenectady, N. Y
8018 Volz, Philip, Newark, N. J.
8019 Harrison, A. W., Los Angeles, Cal.
8020 Fottler, Jacob A., Kingston, R. I.
8021 Lewis, Augustus P., Chicago, Ill.
8022 Reed, Franklin H., Chicago, Ill.
8023 Ellis, Isaac K., Burlington, Vt.
8024 Ludlow, George R., N. Y. City.
8025 Lunt, R. L., Philadelphia, Pa.
8026 Randolph, R. J., Jr., Ampere, N. J.
8027 McWhorter, W. A., Birmingham, Ala.
8028 Wright, E. A., West Allis, Wis.
8029 Creedy, Fred, Wilkinsburg, Pa.
8030 Piper, Charles M., New York City.
8031 Woodring, Fred K., Titusville, Pa.
8032 Thorp, I. Jay, Brooklyn, N. Y.
8033 Hickman, Charles I., Chicago, Ill.
8034 Jones, T. N., Jr., Richmond, Va.
8035 Hideichie, Oana, Tokio, Japan.
8036 Simpson, T. W., Lowell, Mass.
8037 Dapprich, Carl E. L., Chicago, Ill.
8038 Hausell, C. E., Lafayette, Ind.
8039 Russell, R. E., Schenectady, N. Y.
8040 Albrecht, F. C., Wilkinsburg, Pa.
8041 Brooks, H. B., Washington, D. C.
8042 Christy, J. B., New Haven, Conn.
8043 Hutchinson, H. D., Chicago, Ill.
8044 Mulligan, Barry, Wilkinsburg, Pa.
8045 Rose, Wm. H., Washington Barracks, D. C.
8046 Spencer, F. A., Worcester, Mass.
8047 Van Winckle, O. B., Toronto, Can.
8048 Walton, J. A., Baltimore, Md.

8049 Young, John, Welland, Can.
8050 Silberberg, Leon, Baltimore, Md.
8051 Porter, E. H., Philadelphia, Pa.
8052 Carter, R. A., New Rochelle, N. Y.
8053 Hanson, Frank H., Madison, Wis.
8054 Hangan, Charles M., Chicago, Ill.
8055 Cunningham, J.A., Bay City, Mich.
8056 Heinemann, G., Philadelphia, Pa.
8057 Arnold, M. E., Philadelphia, Pa.
8058 Pollard, W. S., Philadelphia, Pa.
8059 Manwaring, A. H., Phila., Pa.
8060 Couch, Herbert B., Lincoln, Neb.
8061 Wreaks, Hugh T., St. George, S.I.
8062 Woodbury, F.P., New York City.
8063 Roszel, R. J., Philadelphia, Pa.
8064 Carr, Charles C., Chicago, Ill.
8065 Carpenter, L. M., Girardville, Pa.
8066 Burch, E. C., Wilkinsburg, Pa.
8067 Hatch, B. E., Willimantic, Conn.
8068 Martin, K. G., New York City.
8069 Allger, Everette E., Bellwood, Pa.
8070 Sutherland, J. A., Saratoga, N. Y.
8071 Griest, T. H., Philadelphia, Pa.
8072 Broomall, A.L., Portchester, N.Y.
8073 Bartlett, P. H., Philadelphia, Pa.
8074 Engler, John, Brooklyn, N. Y.
8075 Blume, L. F., Ithaca, N. Y.
8076 Sprout, S., San Francisco, Cal.
8077 Peterson, Geo. F., Miller, Ind.
8078 Walz, Geo. J., Steelton, Pa.
8079 Beuttell, A. W., N. Y. City.
8080 Crisson, George, Hoboken, N. J.
8081 Elkas, Isaac, St. Louis, Mo.
8082 Hazeltine, L. A., Hoboken, N. J.
8083 Forster, Wm. D., Phila., Pa.
8084 Getts, F. E., Chicago, Ill.
8085 Gleim, T. R., Landsdowne, Pa.
8086 Ives, Robert S., Highwood, Ia.
8087 Kilpatrick, J. L., Phila., Pa.
8088 Mouradian, H., Philadelphia, Pa.
8089 Nattian, E. J., Philadelphia, Pa.
8090 Palmer, G. H., Telluride, Colo.
8091 Parker, Geo. A., Cleveland, O.
8092 Popp, L. W., Madison, Wis.
8093 Ramsey, G. W., Washington, D.C.
8094 Hovde, L. E., Hatfield, Wis.
8095 Collis, A. G., Manchester, Eng.
8096 Schlombs, W., Mexico City, Mex.
8097 Skacelik, Joseph, Toronto, Ont.
8098 Throop, F. W., Power Glen, Ont.
8099 Craig, Ira L., Waterloo, Ia.
Total, 130.

Applications for Transfer

Recommended for transfer by the Board of Examiners, November 13, 1908. Any objection to these transfers should be filed at once with the secretary.

Remigio Jiminez,
Walter Reichel,
Samuel Lindzey Nicholson,
Willard Gilbert Carlton,
Severn D. Sprong,
George W. Patterson,

Sections and Branches

University of Arkansas Branch

At the meeting of the University of Arkansas Branch held on October 14, 1908, the following officers were elected: C. R. Rhodes, chairman, F. S. White, secretary and treasurer. An executive committee was also elected, and plans for conducting the Branch were discussed. Sixteen members attended the meeting.

The November meeting was held on the 11th instant, in the engineering hall. Mr. C. R. Rhodes presided. Mr. P. G. McKinley was elected a member of the executive committee. Professor W. N. Gladson read a paper on "Development of Water Power." He was followed by Professor Ripley who made a few remarks on water-power plants, outlining the possibilities and citing some excellent examples.

Armour Institute of Technology Branch

The second meeting of this Branch was held in Chapin Hall, October 15, 1908. The evening was devoted to electrons, and a paper on the subject was presented by Professor G. E. Marsh. The first part of the paper related to the consideration of the fundamental features of electromagnetic theory. The properties of a charge moving with a constant velocity and with an accelerated velocity received considerable attention. The relations of a moving charge, current, magnetism and radiation were considered in accordance with this theory. Attention was also called to the question of electric inertia, and mention was made of the possible outcome of modern electric hypotheses in providing a more satisfactory explanation for the material mass of a body. The relation between self-induction and the other quantities involved in the phenomena of a moving charge were clearly brought out. After providing a good ground work which was in agreement with known facts and accepted theories, the speaker then took up the subject of electrons proper. In this connection the works of Kelvin, J. J. Thomson, Lenard, Reghi and others were spoken of. The determination of the velocities, electric masses, charges and dimensions of both positive and negative electrons were given. The epoch making investigations of J. J. Thomson in the determination of the mass in charge of an individual negative electron was dwelt upon owing to the beauty of the experimental methods employed. The ionization of gases through the agency of electrons was briefly described. The paper aimed at conveying an easily comprehended exposition of the more elementary characteristics of the electron. The reading was followed by a spirited discussion on a wide range of subjects suggested by the paper.

The third meeting of the Branch was held on November 5, 1908, with Chairman Simpson presiding. After the regular business had been transacted, the subject of examination questions as proposed by the educational committee of the Institute was taken up and discussed, and acted upon favorably. It was proposed, in order to obtain wider information on standard practice in electrical engineering in its various phases, that the Branch be divided into six committees of five members each, whose duties for the ensuing year will be to obtain data and information along special lines in electrical engineering; the chairmen of the respective committees to form an editing committee and publish at the end of the school year such information as may have been obtained and distribute copies to the members of the Branch. The proposition was favorably considered, and it was voted to put it into practice. The paper of the evening, on the subject of selection of railway motor equipments, was presented by Mr. G. I. Stadeker. After touching upon general considerations the speaker took up in detail the various influences and conditions which determine the final selection, such as gear ratios, grades, curves, distance between stops, speed, load, etc., discussing these points independently and also in their relation to each other. Mr. Stadeker also described a system of plotting speed-time curves and an analysis of the system, which he stated so far as he was aware, was different from the method usually employed. An interesting discussion followed the presentation of the paper.

BALTIMORE SECTION

The Baltimore Section held its regular monthly meeting in the Westport power house of the Consolidated Gas, Electric Light and Power Company, on Friday, November 13, 1908, at 8 p.m. On this occasion the members of the Section were the guests of the C. G. E. L. & P. Co., and the total attendance at the meeting numbered 320. Mr. A. S. Loizeaux, electrical engineer of the Consolidated Gas, Electric Light and Power Company, presented a paper entitled, " The Generation and Distribution of Electricity for Light and Power in Baltimore City." The paper was illustrated by lantern slides. After the presentation of the paper the audience, in small parties, was conducted on a tour of inspection about the plant by the company's employes, after which a collation was served in one of the galleries.

UNIVERSITY OF CINCINNATI BRANCH.

This Branch had a meeting on November 17, 1908, which was held at the university. Mr. C. R. Wylie presided.

After disposing of the regular routine business, a paper was read by Mr. Clarence Winder, on " Acyclic Generators ". Considerable discussion followed the reading of the paper, after which the meeting was adjourned.

BOSTON SECTION

The first regular monthly meeting of the Boston Section was held on Wednesday evening, October 21, 1908, at the auditorium of the Edison Building, Professor A. E. Kennelly presiding. About 125 members and guests were present. Charles M. Allen, M. S., professor of experimental engineering at Worcester Polytechnic Institute, presented an extremely interesting paper on " Field Testing of Water Wheels by Dynamometers ", which was illustrated by lantern slides. This was followed by a discussion, at the close of which Professor Allen was given a vote of thanks.

UNIVERSITY OF COLORADO BRANCH

This Branch held its regular meeting on October 22, 1908. Mr. H. H. Watters presided. The program for the evening was as follows: A paper on " Troubles on Telephone Lines ", by Mr. M. H. Putnam. The first of a series of talks on practical wiring, by Professor H. Jenkins. A paper on " The Mercury-Arc Rectifier ", by Mr. H. H. Watters.

FORT WAYNE SECTION

A meeting of this Section was held on November 12, 1908, at the Homestead Cafe, and was well attended. The meeting was preceded by the usual informal dinner, which was followed by the executive session. Mr. J. J. Kline presented the paper of the evening, entitled " Paralleling of Alternators." The discussion that followed was so prolonged that it was necessary to adjourn the meeting without some of the members being heard, and a committee was appointed to reopen the discussion at the next regular meeting. At this meeting Mr. E. A. Barnes, superintendent of the Fort Wayne Electric Works, will present a paper on " Choice of Power for Industrial Purposes."

ITHACA SECTION

The first meeting of the Section for the college year was held on Friday, October 30, 1908. The program comprised an original paper by Mr. J. G. Pertsch, on the general subject of " Alternating Current Line Losses ". Mr. Pertsch gave a summary of the investigations which have led up to Mr. Mershon's latest work, with especial reference to the researches conducted locally by Professor Ryan.

Following Mr. Pertsch's paper was an abstract of Mr. Mershon's Atlantic City convention paper, prepared and delivered by Mr. W. K. Page. This was illustrated by lantern slides made for the occasion. The speaker brought out the essential features of the paper, and led up to a very interesting discussion by the members present. After the discussion the entertainment committee served refreshments. An informal smoker brought the exercises of the evening to a close.

This meeting is the first held in accordance with the plan laid out by the local program committee for the coming year. The plan briefly is as follows: Alternate meetings will be devoted to discussions of the New York and other Institute papers, and addresses by prominent local and out of town engineers. The responsibility for the programs for the meetings is divided between two sub-committees. One of these, under the direction of Professor F. Bedell, who is also chairman of the entire program committee, invites and entertains speakers from outside. The other sub-committee, known as the discussion committee, under the direction of Mr. L. F. Blume, arranges for the abstracts and discussions. In order that this committee may be familiar with the practical experience of the local members, a canvass of the entire junior and senior classes, comprising nearly six hundred men has been made. Each student has been asked to write down on a printed form every detail of his practical experience. Thus in preparing for a given discussion the committee goes over this record, picking out the names of men who have had experience along the line of the paper under discussion. This feature has already proved of the greatest value, and it was not very difficult to effect. The discussion committee has also laid down a most important principle; namely, that each meeting shall as far as possible be self-contained. The abstract of any particular paper will always be preceded by what may be termed original foundation papers. This is necessary to prepare the audience for the proper appreciation of the topic.

At a business meeting held before the discussion a local tax of one dollar per member was decided upon. This is necessary to defray expenses not properly chargeable to the Institute. Mr. P. T. Vanderwaart was elected to represent the enrolled Students on the local executive committee. The entertainment committee for the year was appointed, with Mr. F. C. Loring as chairman.

At the present time there are three Members and twelve Associates connected with the Ithaca Section. The secretary has signed the enrolment blanks of 138 Students, most of whom have already paid their enrolment fee. Altogether the work starts out with promise of success, with largely increased enrolment, and growing interest.

KANSAS STATE AGRICULTURAL COLLEGE

The October meeting of this Branch was held in the electrical engineering lecture room on the 13th instant. Thirty-two members and guests were present at the meeting, which was presided over by Mr. W. L. Enfield. Ten new names were presented for membership and were accepted. In order to acquaint prospective members with the work of the Branch, the following program was given: "What is the A.I.E.E.?", by K. H. Logan. Review of Institute paper entitled "Advantages of Membership in the Local Branch of the A.I.E.E.", by W. L. Enfield. Mr. Grover Kahl, a General Electric Company student apprentice, gave a short talk on the work of the apprentice.

UNIVERSITY OF KANSAS BRANCH

This Branch held a meeting on October 22, 1908. No executive business was transacted. Messrs. Jones and Thiele presented discussions on the subject of lightning protection. The discussions included a review of the papers by Messrs. J. F. Vaughn and N. J. Neall, presented before the Institute on May 19, 1908, and also of the paper by E. E. F. Creighton, on "Measurements of Lightning", presented at the Atlantic City convention.

Another meeting was held on November 5, 1908, presided over by Professor M. E. Rice; at which there was an attendance of 30. The following officers were elected for the ensuing year; Ray Jones, chairman, V. S. Foster, vice-chairman, George V. Emery member of the executive committee. Mr. A. J. Groesbeck opened a discussion on the convention paper of J. L. Woodbridge, "Application of Storage Batteries to Regulation of Alternating-Current Systems." Mr. W. F. Thiele led a discussion on Mr. Fraser's convention paper on "Some Engineering Features of the Southern Power Company's System.

LEHIGH UNIVERSITY BRANCH

A meeting of the Lehigh University Branch was held in the physical laboratory on October 20, 1908. On conclusion of the executive business, President Garrison made a few opening remarks, after which the following papers were presented: "Telephone Practice," by H. G. Harvey, "Esperanto," by R. P. Heller, "Dynamo Testing," by Mr.

Petty. The meeting was followed by a banquet.

The second meeting took place November 13. Mr. A. S. Garrison presided, and the total attendance numbered 74. It was proposed that the yearly program be dispensed with and monthly programs be prepared. A motion to this effect was carried. Mr. Nichols, who is conducting some experiments with a flaming arc lamp at Philadelphia, gave an illustration of the experiments and a talk on the subject. Mr. F. T. Leilich presented a paper on the oscillograph, explaining his apparatus, and threw on the screen 28 slides showing wave-form of various e.m.f. currents used in the laboratory. The meeting was followed by a lunch.

LOS ANGELES SECTION

The Los Angeles Section held its regular meeting on Tuesday, October 20, 1908, at the University of Southern California. There was an attendance of 22 members and 45 visitors. A very interesting paper was presented by Professor W. R. Bowker, on " Some Commercial, Economic and Practical Notes Appertaining to Street Railway Enterprises," which was discussed by Mr. V. L. Benedict. Mr. C. A. Copeland abstracted the Institute paper on " High Potential Underground Transmission." Messrs. E. R. Northmore and R. E. Cunningham took part in the discussion that followed. The Section took formal notice of the death of Dr. F. A. C. Perrine, and the secretary was instructed to send a communication to Mrs. Perrine conveying the sympathy of the members of the Section.

MINNESOTA SECTION

By invitation, the Minnesota Section met with the Engineers' Society of the University of Minnesota, at the university, on October 28, 1908. Fifteen members of the Section were present at the meeting. Mr. Henry J. Gille, of the Minneapolis General Electric Co., delivered an address on the subject of " Business Qualifications of an Engineer."

UNIVERSITY OF MISSOURI BRANCH

This Branch held a meeting on October 16, 1908, at Columbia, Mo. Professor H. B. Shaw presided, and 20 members and visitors were in attendance. Professor A. E. Flowers presented the Institute paper on " High Tension Underground Transmission." The speaker outlined methods of applying insulation to cables to secure maximum resistance to puncture, and gave exact data as to inductive losses, dielectric losses with cables, and eddy current losses in cable sheaths. He also spoke of the economical limits of voltage in underground cable transmission, referring to a recent publication in Electrical Engineering by J. B. Sparks. The particular case of surges in cables was considered in the general discussion, and this part of the Institute paper aroused special interest.

MONTANA AGRICULTURAL COLLEGE BRANCH.

The regular monthly meeting was held in the electrical lecture room, November 13, 1908, Mr. B. S. Hurd presiding. It was decided to establish a question box for the purpose of discussing questions of interest concerning electrical subjects, more particularly for the benefit of members of the Branch. A committee was appointed to report upon the advisability of having a special electrical issue of the college monthly. Mr. C. T. Booker was appointed chairman of a committee to take charge of the electrical show to be given during the college year. Mr. Lisle Henderson was appointed regular correspondent to the college monthly. A program committee was appointed, constituted as follows: C. T. Booker, R. B. Barnard, A. S. Brown. Mr. Bert S. Hunt then delivered an address on " Vacation Experiences ". He was employed during his vacation by the Madison River Power Company, being engaged in repairing high tension transformers that had been damaged by lightning, and in power line construction.

UNIVERSITY OF NEBRASKA BRANCH

A special meeting of the University of Nebraska Branch was held on October 22, 1908, for the purpose of electing officers to fill the vacancies caused by the failure of a number of Students to return to the university this fall. Mr. V. A. Hollister was the presiding officer, and there was an attendance of 14. The following officers were elected: E. R. Pelster, treasurer, H. C. Currier, recording secretary. A letter from Mr. Charles W. Stone, chairman of the Institute increase of membership committee, was read and discussed. It was moved that the first regular meeting be held on Wednesday, November 4. Vice-president Hollister promised to arrange a satisfactory program for this meeting, but owing to the short time in which to make the arrangements he could not announce the details.

OREGON AGRICULTURAL COLLEGE BRANCH

The preliminary meeting of the year of the Oregon Agricultural College Branch was held in the mechanical hall, October 16, 1908. The meeting was called for the purpose of organizing and electing officers for the ensuing year. The following were elected: S. H. Graf, chairman, C. Christiansen, secretary. Executive committee, S. H. Graf, T. M. Gardner, E. V. Hawley, C. L. Knopf, D. F. Morgan. Last year only seniors were admitted to membership. All of these having been graduated, it was decided to admit junior students this year in order to increase the local membership.

The first program meeting was held on October 26, 1908. It was well attended and much interest was displayed as evidenced by the discussion following each paper. Mr. C. L. Knopf, gave a brief, yet comprehensive, history of the Institute and the work it has accomplished. He stated that its membership included all the well-known engineers in America and many of those in foreign countries. Mr. E. V. Hawley abstracted the Institute paper on " High Potential Underground Transmission." The paper brought out many points which have baffled those studying long distance transmission lines, with special reference to lines built in California, and was well received. Professor T. M. Gardner explained to prospective members the advantages of belonging to the Institute and showed how the student would be benefited by being a member.

PITTSBURGH SECTION

The regular monthly meeting of the Pittsburgh Section was held on November 10, 1908, in the Carnegie Institute. Mr. W. Edgar Reed, chairman, presided. Notwithstanding the inclemency of the weather, 22 were present at the informal dinner held at the University Club, and 138 attended the meeting immediately following the dinner. The mining companies and the electrical profession in the entire surrounding district were well represented at the meeting, and among others present were some engineers from the United States Geological Survey. The subject of the evening was " Electricity in Mines ", an original paper presented by Mr. George R. Wood, consulting electrical engineer, of Pittsburgh, Pa., who gave a very complete outline of the application of electricity to coal mining. The lecture was profusely illustrated by lantern slides. The paper was discussed by Messrs. F. L. Sessions, W. A. Thomas, T. H. Schoepf, J. N. Mahoney, F. C. Albrecht, H. L. Brown, and H. W. Fisher.

The subject for the next meeting will be " Some Experiences in the Applications of Gas Power in the Operation of 60-Cycle Industrial Plants, With Special Reference to the Plant of the Union Switch & Signal Company ", an original paper by Mr. J. R. Bibbins.

PITTSFIELD SECTION

The first meeting of the season of the Pittsfield Section was held at Wendell Hotel, November 4, 1908. The attendance numbered 165—the largest in the history of the Section. Mr. W. A. Hall, chairman, presided. Before introducing the first speaker, Mr. Hall outlined briefly the history of the Section and in a general way mentioned its plans for the future. He then introduced Dr. C. P. Steinmetz, who spoke on "Light and Illumination." Dr. Steinmetz first touched briefly on the form of illumination used in olden times, which consisted of nothing more than burning sticks, and later upon the development of the crude tallow candle. He then described the more modern form of light producers, such as the carbon filament electric lamp and the mantle gas lamp, and the still more recent types such as the tungsten and tantalum incandescent lamps and the various forms of flaming arc lamps, also several types of the vacuum type of lamp. In connection with each lamp Dr. Steinmetz gave a very clear description of the energy required for operation, the efficiency and light giving qualities, pointing out the advantages, disadvantages, and limitations. He then outlined the modern theories of light and illumination and indicated the lines along which we may look for further advancement.

The second speaker of the evening, Mr. Ralph W. Pope, was next introduced. Mr. Pope told of the early days of the Institute 'and outlined its remarkable growth from its inception down to the present time. At some of the early meetings in New York the attendance numbered 25 or less. Today large and interesting meetings are held in all parts of the country, and the membership numbers over 6,000. Mr. Pope congratulated the Section on its flourishing condition and well attended meetings. He spoke very highly of the Institute in general and felt that every local member of the Section following electrical engineering work should become a member of the Institute.

Chairman Hall then called on Mr. H. W. Tobey, secretary of the Section. Mr. Tobey felt that the Section had been particularly fortunate in securing Dr. Steinmetz and Mr. Pope for its opening meeting, and after a brief description of the plans for the coming season mentioned the speakers who had already been secured, together with the subjects upon which they are to address future meetings. Mr. J. M. Gilmore, chairman of the local membership committee was next called upon, and he made the gratifying announcement that the total membership of the Section had increased to 265, a gain of 50 over last year. He then described the arrangement between the Pittsfield and Schenectady Sections whereby members could be transferred from one to the other, which also provided that season tickets of either Section would be honored by the other. A social half hour concluded the exercises of the evening.

Prior to the opening of the meeting a dinner was served in honor of the speakers. Those present were: Dr. C. P. Steinmetz, Ralph W. Pope, C. C. Chesney, William Stanley, Stephen D. Field, F. R. Whittlesey, Joseph Insull, W.A. Hall, J. Faccioli, W.J. Wooldridge, I. P. Hayden, H. P. Ball, B. W. Tobey, I. P. Thompson.

PURDUE UNIVERSITY BRANCH

At the meeting of the Purdue University Branch held October 6, 1908, Mr. E. R. Candor gave a very interesting talk on "Power Development in Colombia, South America." As Mr. Candor has lived a good part of his life in the country of which he spoke and is thoroughly familiar with its characteristics and people, the subject proved most entertaining. He pointed out the opportunities for the young engineer in South America, particularly in Colombia, on account of its unlimited and undeveloped natural resources. He stated that one great drawback to progress is the lack of transportation facilities, especially around Bogota, the capital of Colombia. It is a city of over 100,000 population, but practically the only way to obtain supplies is by mule-back for a distance of about one hundred miles, the altitude of the city rendering the construction of a steam road difficult. According to Mr. Candor the chances for an electric road are very favorable, enormous power being available from the rapids at Honda, at one end of the route. The construction of such a road would present no great difficulties up to within thirty miles of Bogota, but here it would be necessary to overcome a rise in elevation of 7,500 feet in thirty miles. Mr. Candor exhibited some interesting views of Colombia and Bogota, and succeeded in his endeavor to show what an opening the natural resources of the country offer to the energetic engineer.

Another meeting was held on October 20, 1908, in the lecture room of the electrical building. Mr. J. R. Ong presided, and 33 members were present. The Institute paper on " High Potential Underground Transmission ", presented at New York, was discussed. Mr. Doering gave in brief the general contents of the paper as a whole. Messrs. Aldridge, Bradfield and Gates then took up the paper by parts and discussed them in detail.

San Francisco Section

The September meeting of the San Francisco Section was held on the 24th instant, Mr. P. M. Downing presiding, with a total attendance of 51. There was no executive business. The paper of the evening, on " High Tension Insulators ", was presented by Mr. H. Naack.

One hundred and one members and visitors were present at the October meeting, held on the 30th instant. Mr. F. G. Baum presided at this meeting. Mr. A. H. Babcock read the paper of the evening, entitled " Some Problems Encountered in Trunk-Line Electrification ". An informal discussion followed.

Schenectady Section

The regular meetings of the Schenectady Section began on October 29, 1908. At this meeting Mr. E. W. Rice delivered a lecture on the " Pioneer Developments within the General Electric Company." Subsequent meetings were held on November 5, 12, and 19, at which Dr. C. P. Steinmetz gave a series of three lectures on the subject of thermodynamics. It was Dr. Steinmetz' intention to cover the subject in the course of these three lectures, but it was found impossible, and he will complete the series with a fourth lecture on December 3.

The membership of the Section is now between 800 and 900, and earnest efforts are being made by the membership committee to bring the number up to 1,000. The attendance at the four meetings above mentioned was between 350 and 400, divided about equally between local and Institute members. The financial condition of the Section is such that it is believed the Section will continue to be self-sustaining. The General Electric Company has consented to furnish the *General Electric Review* free of charge to all the members of the Section, in return for which a synopsis of each lecture delivered will be furnished to the *Review*. The next meeting of the Section will be held on December 3.

St. Louis Section.

At the first meeting of the season, of the St. Louis Section; held October 14, 1908, 33 members and guests were present. In the course of the business session the executive committee was empowered to raise by assessment sufficient funds for the purpose of entertainment. Announcement was made of a plan under consideration to devote a meeting later in the season to the discussion of a "question box". The paper of the evening, on " The Fatigue of Insulation ", by Professor A. S. Langsdorf, of Washington University, was interesting. The paper gave the results of a large number of tests of various kinds of material when subjected to alternating electric pressures. The arrangement of the testing apparatus was fully described. Curves were shown of the relations which were found between the time of breakdown and the intensity of electrical pressure with uniform frequency, and between the time of breakdown and frequency with uniform pressure. The conclusions drawn were that insulating materials have a fatigue of insulation corresponding to the fatigue in the strength of materials. In the discussion that followed the paper the theory was advanced that the results obtained might be due to thermal effects instead of electrical.

The November meeting was held on the 11th instant, 50 members and guests being present. After a brief business session the paper of the evening was presented by Mr. H. M. Beck, of Chicago, chief engineer of the operating department of the Electric Storage Battery Company. Published information on storage batteries being rather limited, the paper proved of special interest. Batteries were considered from the operating standpoint, and care, maintenance and operation were fully described. Numerous lantern slides were used to illustrate the paper. A sample cell, complete with plates, and samples of the latest types and of old types, of hydrometers for testing the specific gravity of the electrolite were exhibited. The meeting was followed by a social hour during which light refreshments and cigars were served.

SEATTLE SECTION

There was an unusually large attendance at the meeting of this Section held at the Chamber of Commerce on October 17, 1908. In the absence of Chairman Harisberger, Professor Magnusson presided. The invitation of the Automatic Telephone Company to the members of the Section to visit the company's sub-station was accepted. The inspection trip will take the place of the regular November meeting. The members will proceed to Tacoma by Steamer Indianapolis, taking dinner aboard. After the visit to the plant they will return by the Interurban Electric Railway, leaving at 9:15 p.m. An enjoyable trip is anticipated. The matter of entertaining visiting engineers during the Alaska-Yukon-Pacific Exposition was taken up and a motion made that a committee of three be appointed to confer with similar committees from the Pacific Northwest Society of Engineers and the Northwest Power and Light Association to arrange for properly receiving visitors. Three applications for local membership were presented and accepted. The meeting closed with the paper of the evening on the subject of "Comparative Performance of Single-Phase and Direct-Current Railway Motors", presented by Mr. A. A. Miller. Mr. Miller stated that the alternating-current railway motor has long since passed the experimental stage and bids fair to drive the direct-current motor from the field. He declared that sparking troubles at the commutator have been satisfactorily eliminated. An interesting discussion followed the presentation of the paper.

STATE COLLEGE OF WASHINGTON BRANCH

The first meeting of the year of this Branch was held October 20, 1908, in the Mechanical Building. Officers for the year were elected as follows: Professor H. V. Carpenter, chairman, Professor M. K. Akers, local secretary and treasurer, J. A. Smith, branch secretary and treasurer. The following were elected members of the executive committee: E. F. Keyes, J. T. Percival, and F. A. Phipps. Plans for the year were discussed, and a motion carried that the Institute Branch be made a parent to the student organization, the Mechanical and Electrical Society. The meeting was well attended and the outlook for a successful year seems very promising.

SYRACUSE UNIVERSITY BRANCH

The regular monthly meeting was held Thursday evening, November 5, 1908. Mr. L. L. Cross gave an abstract of the Institute convention paper by Dr. J. B. Whitehead, "From Steam to Electricity on a Single-Track Road." Professors Graham and Acheson and Mr. Yoe took part in the discussion which followed. No executive business was transacted.

UNIVERSITY OF TEXAS BRANCH

This Branch held its regular meeting on the evening of October 30, 1908. Ninteeen members were present. Mr. J. M. Stevenson, who represented the Branch at the Institute convention at Atlantic City in June, read a paper regarding the convention, which proved of great interest to those present, particularly the report of the various Section and Branch representatives. Mr. McAlister reviewed the Institute paper entitled "The Relation of the Manufacturing Company to the Technical Graduate", and the paper on "The New Method of Training Engineers" was reviewed by Mr. Maesson. Mr. White also read another of the Institute convention papers, entitled "The Relation of the Manufacturing Company to the Technical Graduate." All of the papers were discussed.

TOLEDO SECTION

This Section held an interesting meeting on Friday evening, November 6, 1908, in the Builders' Exchange. The address of the evening, by Mr. A. L. Eustice, went into the problem of recent work in high efficiency illumination, especially the development of incandescent units of the Nernst glower type, as well as the meridian, gem, tungsten and tantalum. The address was illustrated by numerous lantern slides, for the purpose of comparison. Considerable attention was given to the structural features of the new Westinghouse-Nernst lamp and the relative merits of the tungsten. A spirited discussion followed the paper, which was participated in by Messrs. H. S. Hall, of the National Electric Lamp Association, Cleveland, Ohio, G. C. Osborne, of the General Electric Company, lamp department, Harrison, New Jersey, and C. R. McKay. The meeting room was brilliantly illuminated by several types of Nernst lamps which in addition to effective lighting displayed some very attractive forms of electric fixtures. In speaking of tungsten lamps Mr. Osborne exhibited and connected up several, and subjected them to violent handling while lighting, in order to demonstrate that these units are not frail or fragile. At the close of the exercises a letter was read from the Ohio Society of Mechanical, Electrical & Steam Engineers, inviting the members of the Section to attend the society's meetings at Hotel Secor, Toledo, November 20 and 21, 1908. The invitation was accepted.

WASHINGTON UNIVERSITY BRANCH

The second meeting of this Branch was held in Cupples Hall II on Wednesday afternoon, November 11, 1908. Ten members were present. Mr. W. D. Barnes read an abstract of Mr. H. St. Clair Putnam's paper on "Conservation of Power Resources", presented at the Conference on the Conservation of Natural Resources at Washington last May. Mr. Barnes stated that the visible hard coal supply of the country would be exhausted within 70 years at the present rate of consumption. There are 30,000,000 h.p. available in our water supply, which should be utilized. He pointed out the importance of coöperation of the canal, timber and power interests for the benefit of the general public. The discussion that followed brought out some points of interest in regard to solar engines and gases from blast furnaces. Messrs. C. M. Duncan, F. C. Hirdler, and G. W. Lamke, took part in the discussion.

UNIVERSITY OF WISCONSIN BRANCH

This Branch held its first meeting of the year in the Madison City Library building on the evening of October 28, 1908. It was one of the largest meetings the Branch has ever held, nearly

100 being present. Mr. C. E. Carter was elected chairman, and Professor J. W. Shuster, secretary. Messrs. W. E. Wickenden and F. S. Culver were elected members of the executive committee. The business being disposed of, a very interesting program was carried out. An original paper prepared by Messrs. E. H. Kifer, C. E. Carter and C. A. Semrad, on " Some Operating Features of a 500 kw. Turbo-Generator" was presented by Mr. Kifer. The paper was illustrated by a number of enlarged sketches and tables, and an animated discussion followed the presentation. The Institute paper on " High Tension Underground Cables " was abstracted by Mr. Pott, and also discussed. The attendance and manifest interest at this first meeting gives promise for a most successful year for the Branch.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

The second meeting of this Branch was held Friday night, October 23, 1908, in the Electrical Engineering Building, Salisbury Street. Mr. D. H. Mace was elected to serve on the executive committee. The president, Mr. F. A. Spencer, announced that Mr. Johnson, of the Ontario Power Company, would speak at the next meeting, November 6, on " Some Features on the Work of the Ontario Power Company of Niagara Falls." The lecture is to be illustrated by a large and excellent collection of lantern slides. Mr. Spencer introduced the first speaker, Mr. L. A. Parkhurst, who gave an account of his work with the American Telephone and Telegraph Company. During the summer of 1907 he was located in New York, working on switchboard cable, later in Pittsfield installing a small test station, and still later in Town Square, Pa., installing an exchange. During the summer of 1908 Mr. Parkhurst was in the company's long distance exchange at Pawtucket, R. I., in the general maintenance department. Mr. Parkhurst stated that although the construction department was better from a remunerative standpoint, he preferred the maintenance department as it afforded more experience. Mr. F. J. Adams, an instructor at the Worcester Polytechnic Institute, gave an account of the twenty-fifth annual convention of the American Institute of Electrical Engineers at Atlantic City last June. Mr. Adams pointed out the social advantages of the convention, and made some remarks respecting the different papers presented there. In conclusion he gave some figures to show that the Worcester Branch ranked very well in comparison with other Sections and Branches of the Institute. Mr. J. A. O'Neil told of his work with the Worcester Consolidated Railway Company, on line construction. He first described the feeder and distribution system, then the different shapes of trolley and methods of suspension, concluding with a few remarks about poles and special work. The last speaker of the evening was Professor A. S. Richey, who gave an account of the convention of the American Street and Interurban Railway Association at Atlantic City. He stated that the attendance was about 3,500, and explained how the meetings had to be divided into sections because of the various and numerous subjects to be treated. Professor Richey who presented the report of the committee on education at this convention, touched briefly upon the report and gave abstracts of several other papers presented. He spoke also of the social features and the completeness of the exhibits at the convention.

The third regular meeting was held Friday evening, November 6, 1908, one hundred and eighty being present. The subject of the evening was a lecture by Mr. Joseph A. Johnson, of the Ontario Power Company, on " Some Features of the Work of the Ontario Power Company of Niagara Falls." Mr. Johnson outlined the hydraulic features of the plant from head-works to tail-race, and then took up the electrical installation in detail. Lightning-arresters and lightning-arrester troubles were also dealt with. The distribution of power was very clearly shown by means of maps, and views of many of the consumers' plants were shown. Special relays developed by the company were described, and many oscillograph records obtained in experimental work were shown. Mr. Johnson has been engaged in much of the experimental and research work that has been undertaken by the company, and therefore was able to deliver a most interesting lecture. It was illustrated by about 100 lantern slides.

Personal

Mr. E. W. Bowness has accepted a position with the Westinghouse Electric & Manufacturing Company in Vancouver, British Columbia.

Mr. Richard F. Warner has resigned from the General Electric Company and has taken a position with Messrs. Frazer & Sale, Limited, of New York, as manager.

Mr. P. Lindeman was appointed, August 1, master mechanic of the Rochester, Syracuse & Eastern R.R. Company, operating about 58 miles of double track, with an office at Newark, New York.

Mr. C. S. Peters, formerly in the engineering department of the Wagner Electric Mnaufacturing Company, St. Louis, Mo., has taken a similar position with the Mechanical Appliance Company, Milwaukee, Wis.

Mr. Hugh A. Brown, attached to the Chicago office of the Crocker-Wheeler Company for several years, has resigned his position to become manager of sales for the Rockaway Coaster Company, Cincinnati, Ohio, in which he has an interest.

Mr. Edgar T. Beaubien has been transferred from the patent bureau of the Western Electric Company's Chicago office to the patent bureau of the same company in New York, where he will be engaged in investigating patent questions arising with that company.

Mr. W. J. Wooldridge has been transferred from the Schenectady, N.Y. Works of to the General Electric Company to their works at Pittsfield, Mass., where he will continue in the transformer engineering department in charge of the commercial engineering section.

Mr. F. J. Foote, electrical engineer for the Westinghouse Electric & Manufacturing Company, formerly of Cincinnati, Ohio, is now looking after the engineering work for the above company in Louisville, Ky. and vicinity. His present address is 539 East Chestnut St., Louisville, Ky.

Orman B. Humphrey, consulting engineer, of Bangor, Maine, who for the past year has been engaged on the preliminary engineering in connection with the Ryegate Light & Power Co., hydroelectric development on Wells River, Vermont, has completed his work, and active construction has begun.

Mr. William E. Kiely, who since 1899 has been managing editor of the Western Electrician, has resigned that position, and has taken up special literary work at 6503 Minerva Avenue, Chicago. Mr. Kiely has shown exceptional ability in his editorial work, and whatever he undertakes will be well done.

Mr. Frank G. Herman severed his connection with the West Jersey & Seashore Railroad Company last August to accept a position with the New Jersey & Pennsylvania Traction Company, of Trenton, N. J. As chief engineer he will have charge of all power-houses and sub-stations, with an office at Yardley, Pa.

Mr. C. L. Proctor has accepted the position of electrical engineer and superintendent of operation of the Athens Electric Railway Company, Athens, Georgia. Prior to this appointment Mr. Proctor was with the General Electric Company, Schenectady, in its testing, foreign and railway departments.

Mr. Richard Heinrich, of Berlin, spent a few days in New York and vicinity, returning home by the Hamburg-American steamship Victoria, November 12. Mr. Heinrich was associated with Mr. C. O. Mailloux, as an official representative of the Institute at the recent International Electrical Congress at Marseilles, France.

Mr. H. G. Fetherling, formerly with the Northern Electrical Manufacturing Company, and later with the Pittsburg office of the Blaisdell Filtration Company, has again associated himself with the Northern Company, as manager of the apparatus department. Mr. Fetherling will be in the home office at Madison, Wisconsin.

Mr. Thomas V. d'Ornellas, electrical consulting engineer to the Peruvian Government, has transferred his residence from calle de Santa Teresa 91, Lima, to calle de Lima 15, Chorrillos, n. Lima. Mr. d'Ornellas has been connected with the electrical department in the Ministry of Public Works of Peru for over three years.

Mr. J. R. Gordon, for many years southern district manager for the Westinghouse Electric & Manufacturing Company, has resigned from that company and accepted a position with the Western Electric Company as power apparatus sales manager for their southern territory, with headquarters at Atlanta. He assumed his new duties on November 1.

Mr. H. B. Kirkland, formerly general sales manager for the National Metal Molding Company, has organized the H. B. Kirkland Company, of which he is president, with Charles F. Boynton as treasurer. The company will act as sales agents for the National Metal Molding Company, in the territory east of the Allegheny mountains, with headquarters at the Postal Telegraph Building, 253 Broadway, New York City.

Mr. W. G. Thummel has resigned his position as chief engineer of the Bartlesville Inter-Urban Railway Company, of Bartlesville, Oklahoma, to take charge of the building of an electric road near St. Louis. Mr. Thummel makes a specialty of small inter-urban roads, handling the engineering, civil and electrical, from the preliminary survey to the operation of the road. He is at present located at 4341 West Belle Place, St. Louis, Mo.

Mr. H. D. Murdock, who has been mechanical and electrical engineer of the Indianapolis & Louisville Traction Company for the past year, at Scottsburg, Ind., has been made superintendent of the company and the position of mechanical and electrical engineer has been abolished. For a number of years, Mr. Murdock was identified with the Westinghouse Electric & Manufacturing Company and later with the Brooklyn Rapid Transit Company.

Henry Floy, consulting engineer, has just returned to New York from a several weeks' business trip in Mexico in connection with the proposed hydroelectric development of El Salto Falls, owned by the Rascon Mfg. & Development Co., which company proposes to transmit electric energy to Matehuala and San Luis Potosi, in both of which towns there is a desirable market. While in Mexico he also inspected the Guanajuato Power & Electric Company's system at Guanajuato, and the Necaxa transmission into Mexico City.

Mr. Walter Dalton, formerly of Philadelphia, who was constructing engineer for James J. Burke & Company, of Salt Lake City, who installed the sampling mills, ore bins and tramway for the Bakala Copper Smelter in California, also with the Salt Lake City office of Chas. C. Moore & Company, and installed for them the hydro-electric plant of the Idaho Consolidated Mines Company, at Belvue, Idaho, has returned to Philadelphia, and is now a member of the engineering staff of the Philadelphia Construction Company.

Illuminating Engineering Society

The next meeting of the New England Section of the Illuminating Engineering Society will be held on Thursday, December 3, 1908, at 7:30 p.m., in the auditorium of the Edison Building, 39 Boylston street, Boston.

Mr. H. W. Moses will read a paper describing the work of the division of illuminating engineering of the Edison Electric Illuminating Company of Boston.

Technischer Verein Officers

At the annual meeting of the Technischer Verein von New York, held in October, the following officers were elected for the year 1908-1909:

F. J. Flocke, president; A. Lebrecht, vice-president; Karl Kaelble, first secretary; Henry Jackson, second secretary; W. Frick, treasurer; H. Meixner, librarian.

Annual Meeting A. S. M. E.

The twenty-ninth annual meeting of the American Society of Mechanical Engineers will be held in the Engineers' Building, 33 West Thirty-ninth street, New York, December 1-4, 1908. The following papers will be presented:

"The Conservation Idea as Applied to the American Society of Mechanical Engineers" (president's address), by M. L. Holman.

Wednesday, December 2

"The Engineer and the People," by Morris Llewellyn Cooke.

"Aeronautics," by Major Geo. O. Squier, Acting Chief Signal Officer, U. S. A.

"A Method of Obtaining Ratios of Specific Heat of Vapors," by A. R. Dodge.

"The Total Heat of Saturated Steam," by Dr. Harvey N. Davis.

"Fuel Economy Tests," by C. R. Weymouth.

"An Automatic System for Firing Fuel Oil," by C. R. Weymouth.

Thursday, December 3.

"Efficiency Tests of Milling Machines and Milling Cutters," by A. L. DeLeeuw.

"Metal Cutting Tools without Clearance," by James Hartness.

"Interchangeable Involute Gear Tooth Systems," by Ralph E. Flanders.

"Durability of Gears in Electric Railway Service," by Norman Litchfield.

"Industrial Photography," by S. Ashton Hand.

"Articulated Compound Locomotives," by C. J. Mellin.

"Liquid Tachometers," by Amasa Trobridge.

"Training Workmen," by H. L. Gantt.

"An Averaging Instrument for Polar Diagrams," by Prof. W. F. Durand.

"Salt Manufacture," by George B. Willcox.

"Reminiscences of a Gas Engine Designer," by L. H. Nash.

"Possibilities of the Gasolene Turbine," by Prof. F. C. Wagner.

Friday, December 4.

"Physical Properties of Carbonic Acid and the Conditions of its Economic Storage for Transportation," by Prof. R. T. Stewart.

"The Slipping Point of Rolled Boiler Tube Joints," by O. P. Hood and Prof. G. L. Christensen.

"Tests on Friction Clutches for Power Transmission," by Prof. Richard G. Dukes.

Obituary

Mr. Edward Victor Baillard, who was a manufacturer of electrical machinery at 24 Frankfort Street, New York City, died on the evening of October 24, 1908, from a pleuritic attack. Mr. Baillard was born in New York City on March 14, 1866. He received a general education in private and public schools in New York. On leaving school in 1881 he took up the study of electricity and its applications, from periodicals and various text-books. He was elected an Associate of the Institute on December 3, 1889, and on January 16, 1895, was transferred to the grade of Member. He is believed to have been the first person to make a practical demonstration of the multiplex telegraph. The experiments were conducted in 1886 by himself and his associate, Mr. A. M. A. Beale, between 253 Broadway, New York City, and Philadelphia, with Mr. Baillard at the New York end and Mr. Beale at Philadelphia. In the course of the experiments eight messages were sent simultaneously over the same wire to eight separate offices. He was widely known in electrical circles as an expert mechanician, making a specialty of solving difficult mechanical problems in the construction of fine electrical machinery, and to his technical knowledge and mechanical skill is due the development to the practical stage, of a number of important electrical inventions.

Elmer Gould Eberhardt, vice-president of the Newark Gear Cutting Machine Company, of Newark, N. J., died on Saturday, November 21, 1908, at the home of his father, Henry E. Eberhardt, 113 Orchard Street, Newark, after a few days' illness. He was born on April 26, 1881, at Newark. Although only 27 years of age at the time of his death, Mr. Eberhardt had established a reputation as a mathematical and inventive genius. When 11 years of age he began his four years' high school course, graduating at the head of his class at 15. Ambitious to still better his education, he entered the Stevens Institute at Hoboken. While at college he was elected president of the French class. After a year at Stevens Institute Mr. Eberhardt left to enter upon his business career, starting as an apprentice in his father's shop. He afterwards decided to go to Cornell University to complete his electrical engineering education, and was graduated from that institution in the class of 1904. On August 5, 1904, he became an Associate of the American Institute of Electrical Engineers. On re-entering his father's employ he at once began to devise improvements for the gear cutting machines manufactured by the firm. A number of his inventions were patented and attached to the machines. Some of his attachments have revolutionized the manufacture of cut glass. He was unmarried, and lived with his parents. His father and mother and four brothers survive him.

Accessions to the Library

The following accessions have been made to the Library of the Institute since the last acknowledgements:

Barrows, W. E. Electrical Illuminating Engineering. New York, McGraw Publishing Co., 1908 (gift of publishers). Price, $2.00 net.

Bureau des Longitudes. Annuaire pour L'an 1909. Paris, Gauthier Villars, 1908 (exchange).

College of Science, Imperial Univ. of Tokyo, Japan. Journal. Vol. XXV. Tokyo, 1908 (exchange).

Doremus, C. A. Robert Hare's Electric Furnace, n.p: n.d. (gift of author).

Forse, W. H., Jr. Electric Railway Auditing and Accounting. New York, McGraw Publishing Co., 1908. Price, $2.00 net (gift of publishers).

General Incandescent Arc Light Co. Bulletin, 1903-1905 (gift of H. W. Tobey).

Institution of Civil Engineers, Minutes of Proceedings. Vol. 172. London, 1908 (exchange).

List of Members, July 1908. London, 1908.

MAYCOCK, W. P. Electric Lighting and Power Distribution. Edition 7, Vol. 1. London-New York, The Macmillan Co., 1908. Price, $1.90 net (gift of publishers).

MEAD, DANIEL W. Water power engineering, theory, investigation and development of water powers. New York, McGraw Publishing Co. Price, $6.00 net (gift of author).

CONTENTS.—Chapter I.—Introduction. II.—Power. III.—Hydraulics. IV.—Water power. V.—Water power continued. VI.—Rainfall. VII.—Disposal of the rainfall. VIII.—Run-off. IX.—Run-off continued. X.—Stream flow. XI.—Measurement of stream flow. XII.—Water wheels. XIII.—Turbine details and appurtenances. XIV.—Hydraulics of the Turbine. XV.—Turbine testing. XVI.—Selection of the turbine. XVII.—Load curve and load factors, and their influence on the design of the power-plant. XVIII.—Speed regulation of turbine water wheels. XIX.—Water wheel governer. XX.—Arrangement of the reaction wheel. XXI.—Selection of machinery and design of plant. XXII.—Examples of water power plants. XXIII—Relation of dam and power station. XXIV.—Principles of construction of dams. XXV.—Appendages to dams. XXVI.—Pondage and storage. XXVII.—Cost, value and sale of power. XXVIII.—Investigation of water power projects.

MONCKTON, C. C. F. Radio-telegraphy. New York, D. Van Nostrand Co., 1908. Price, $2.00 net (gift of publishers).

CONTENTS.—Chapter I.—Electric phenomena. II.—Electric vibrations. III.—Electro-magnetic waves. IV.—Modified Hertz waves used in radio-telegraphy. V.—Apparatus used for charging the oscillator. VI.—(The) Electric oscillator-method of arrangement. VII.—(The) Electric oscillator-practical details VIII.—(The) Receiver-method of arrangement. IX.—(The) Receiver-detecting apparatus and other details. X.—Measurements in radio-telegraphy. XI.—Experimental station at Elmers end-Lodge-Muirhead system. XII.—Radio-telegraph station at Nauen-Telefunken system. XIII.—Radio-telegraph station at Lyngby-Poulsen system. XIV.—Portable stations. XV.—Radio-telephony.

MOTELAY, P. F. Bibliography of Electrochemistry and Allied Subjects. n.p: n.d. (gift of author).

National Association of Cotton Manufacturers. Transactions, No. 84. Boston, 1908 (gift of society).

National Electric Light Association. Thirty-first Convention. Vol. 1. New York, 1908.

National Fire Protection Association. Articles of Association. Officers and committees for the year 1908-1909. Chicago, 1908.

NICHOLS, EDWARD L., AND FRANKLIN, W. S. The Elements of Physics. A college text-book (3 vols). Vol. 2. Electricity and Magnetism. New edition. New York, The Macmillan Co., 1907. Price, $1.60 net (gift of publishers).

Public Service Commission. Report of the Public Service Commission for the first district of the State of N. Y. Vol. 1. Albany, 1908 (gift of commission).

Relative Index. An extension of the Dewey system for the electrical industry. Schenectady, 1903 (gift of General Electric Company).

RICHARDSON, S. S. Magnetism and electricity and the principles of electrical measurement. New York, D. Van Nostrand Co. n.d. Price, $2.00 net (gift of publishers).

CONTENTS.—Part I.—Magnetism. Part II.—Static electricity. Part III.—Current electricity.

SHELDON, SAMUEL, MASON, HOBART, AND HAUSMANN, ERICH. Alternating-Current Machines, being the second volume of Dynamo Electric Machinery. 7th ed. New York, D. Van Nostrand Co., 1908 (gift of publishers).

Stone and Webster Library. Current literature. References, 1907. Boston, 1908 (gift of Electric Railway Journal).

Western Union Telegraph Company. Annual Report of the President to the Stockholders, 1908. New York, 1908 (gift of company).

H. W. WILSON Co., publishers. Reader's guide to periodical literature. Minneapolis, 1908 (gift of McGraw Co.).

[To be continued in January PROCEEDINGS.]

Officers and Board of Directors, 1908-1909

PRESIDENT

LOUIS A. FERGUSON, Chicago, Ill.

JUNIOR PAST-PRESIDENTS.

SAMUEL SHELDON, Brooklyn, N. Y.
HENRY GORDON STOTT, New York, N. Y.

VICE-PRESIDENTS

JAMES G. WHITE, New York, N. Y.
JOHN J. CARTY, New York, N. Y.
W. C. L. EGLIN, Philadelphia, Pa.

CUMMINGS C. CHESNEY, Pittsfield, Mass.
BANCROFT GHERARDI, New York, N. Y.
CALVERT TOWNLEY, New Haven, Conn.

MANAGERS

A. M. SCHOEN, Atlanta, Ga.
PAUL M. LINCOLN, Pittsburgh, Pa.
PAUL SPENCER, Philadelphia, Pa.
WILLIAM S. MURRAY, New Haven, Conn.

MORGAN BROOKS, Urbana, Ill.
HAROLD W. BUCK, New York, N. Y.
PERCY H. THOMAS, Montclair, N. J.
BENJAMIN G. LAMME, Pittsburgh, Pa.

DAVID B. RUSHMORE, Schenectady, N. Y.
W. G. CARLTON, New York N. Y.
CHARLES W. STONE, Schenectady, N. Y.
H. E. CLIFFORD, Boston, Mass.

TREASURER

GEORGE A. HAMILTON, New York, N. Y.

SECRETARY

RALPH W. POPE, New York, N. Y.

PAST-PRESIDENTS

T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
ALEX. GRAHAM BELL, 1891-2.
FRANK J. SPRAGUE, 1892-3.
EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS B. CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1901.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, JR., 1904.5.
SCHUYLER S. WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY GORDON STOTT, 1907-8.

ASSISTANT SECRETARY

FREDERICK L. HUTCHINSON,
33 West 39th Street, New York, N. Y.

GENERAL COUNSEL

PARKER and AARON,
52 Broadway, New York N. Y.

Standing Committees

EXECUTIVE COMMITTEE.

LOUIS A. FERGUSON, Chairman.
139 Adams Street, Chicago, Ill.
JOHN J. CARTY, New York.
C. C. CHESNEY, Pittsfield, Mass.
WM. C. L. EGLIN, Philadelphia, Pa.
GEORGE A. HAMILTON, New York.
RALPH W. POPE, New York.
CALVERT TOWNLEY, New Haven, Conn.

FINANCE COMMITTEE.

CALVERT TOWNLEY, Chairman.
The Connecticut Co., New Haven, Conn.
HAROLD W. BUCK, New York.
BANCROFT GHERARDI, New York.

LIBRARY COMMITTEE.

EDWARD CALDWELL, Chairman.
239 West 39th Street, New York.
W. G. CARLTON, New York.
H. E. CLIFFORD, Boston, Mass.
MAX LOEWENTHAL, New York.
PHILIP TORCHIO, New York.

MEETINGS AND PAPERS COMMITTEE

A. H. ARMSTRONG, Chairman.
G. E. Co., Schenectady, N. Y.
BION J. ARNOLD, Chicago, Ill.
JOHN J. CARTY, New York.
RALPH D. MERSHON, New York.
H. H. NORRIS, Ithaca, N. Y.
C. E. SKINNER, Pittsburgh, Pa.

EDITING COMMITTEE.

GEORGE F. SEVER, Chairman.
Columbia University, New York.
A. H. ARMSTRONG, Schenectady, N. Y.
SAMUEL SHELDON, Brooklyn, New York.

BOARD OF EXAMINERS.

HAROLD W. BUCK, Chairman.
49 Wall Street, New York.
H. H. BARNES, JR., New York.
MAURICE COSTER, New York.
WM. C. L. EGLIN, Philadelphia, Pa.
D. C. JACKSON, Boston, Mass.

SECTIONS COMMITTEE.

PAUL SPENCER, Chairman.
Broad and Arch Streets, Philadelphia, Pa.
H. R. KING, Chicago, Ill.
PAUL M. LINCOLN, Pittsburgh, Pa.
H. H. NORRIS, Ithaca, N. Y.
D. B. RUSHMORE, Schenectady, N. Y.

STANDARDS COMMITTEE.

SAMUEL SHELDON, Chairman.
Polytechnic Institute, Brooklyn, N. Y.
B. A. BEHREND, Milwaukee, Wis.
GANO DUNN, Ampere, N. J.
A. E. KENNELLY, Boston, Mass.
J. W. LIEB, JR., New York.
CHARLES F. SCOTT, Pittsburgh, Pa.
CLAYTON H. SHARP, New York.
C. P. STEINMETZ, Schenectady, N. Y.
S. W. STRATTON, Washington, D. C.

CODE COMMITTEE.

C. W. STONE, Vice-chairman,
G. E. Co., Schenectady, N. Y.
W. H. BLOOD, JR., Boston, Mass.
WASHINGTON DEVEREUX, Philadelphia,
JOSEPH C. FORSYTH, New York.
H. B. GEAR, Chicago, Ill.
FARLEY OSGOOD, Newark, N. J.
GEORGE F. SEVER, New York.
H. S. WARREN, New York.
ARTHUR WILLIAMS, St. Louis, Mo.

LAW COMMITTEE.

H. G. STOTT, Chairman.
600 West 59th Street, New York.
A. E. KENNELLY, Boston, Mass.
J. W. LIEB, JR., New York.
CHARLES F. SCOTT, Pittsburgh, Pa.
SAMUEL SHELDON, Brooklyn, N. Y.

Special Committees

RAILWAY COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
BION J. ARNOLD. Chairman,
181 La Salle Street, Chicago, Ill
E. H. ANDERSON, Schenectady, N. Y.
GEORGE GIBBS, New York.
H. ST. CLAIR PUTNAM, New York.
N. W. STORER, Pittsburgh, Pa.

EDUCATIONAL COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
HENRY H. NORRIS, Chairman.
Cornell University, Ithaca, N. Y.
H. E. CLIFFORD, Boston, Mass.
GANO DUNN, Ampere, N. J.
G. A. HOADLEY, Swarthmore, Pa.
C. O. MAILLOUX, New York.
CHARLES F. SCOTT, Pittsburgh, Pa.
CHARLES P. STEINMETZ, Schenectady, N.Y

HIGH-TENSION TRANSMISSION COMMITTEE.

(Sub-com. of Meetings and Papers Committee.)
RALPH D. MERSHON, Chairman.
60 Wall Street, New York.
C. C. CHESNEY, Pittsfield, Mass.
PAUL M. LINCOLN, Pittsburgh, Pa.
W. S. MOODY, Schenectady, N. Y.
W. N. RYERSON, Niagara Falls, N. Y.

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

H. G. STOTT, Chairman.
600 West 59th Street, New York.
W. L. ABBOTT, Chicago, Ill.
W. H. BLOOD, JR., Boston, Mass.
JOHN H. FINNEY, Washington, D. C.
P. G. GOSSLER, New York.
F. A. C. PERRINE, New York.
CHARLES H. PORTER, Boston, Mass.

COMMITTEE ON INDUSTRIAL POWER.

D. B. RUSHMORE, Chairman.
G. E. Co., Schenectady, N. Y.
CHARLES DAY, Philadelphia, Pa.
GANO DUNN, Ampere, N. J.
R. S. FEICHT, Pittsburgh, Pa.
E. W. LLOYD, Chicago, Ill.
B. R. SHOVER, Gary, Ind.
R. B. WILLIAMSON, Milwaukee, Wis.

COMMITTEE ON INCREASE OF MEMBERSHIP.

C. W. STONE, Chairman.
G. E. Co., Schenectady, N. Y.
A. W. BERRESFORD, Milwaukee, Wis.
HENRY L. DOHERTY, New York.
GANO DUNN, Ampere, N. J.
BANCROFT GHERARDI, New York.
F. L. HUTCHINSON, New York.
H. R. KING, Chicago, Ill.
S. M. KINTNER, Pittsburgh, Pa.
H. L. SMITH, Schenectady, N. Y.
SEVERN D. SPRONG, New York.
W. L. WATERS, Pittsburgh, Pa.
P. B. WOODWORTH, Chicago, Ill.

COMMITTEE ON INTERMEDIATE GRADE OF MEMBERSHIP.

CHAS. F. SCOTT, Chairman.
W. E. & M. Co., Pittsburgh, Pa.
K. L. AITKEN, Toronto, Canada.
WILLIAM McCLELLAN, New York.
GEORGE F. SEVER, New York.
PAUL SPENCER, Philadelphia, Pa.

EDISON MEDAL COMMITTEE.

CHARLES L. CLARKE, Chairman.
120 Broadway, New York.
HENRY L. DOHERTY.
HENRY G. STOTT.
GEO. A. HAMILTON.

T. C. MARTIN.
WM. HAND BROWNE, JR.

JOHN W. HOWELL.
CHARLES F. SCOTT.
SAMUEL REBER.

GANO DUNN.
CHARLES A. TERRY.
W. S. BARSTOW.

CHARLES E. LUCKE.
DUGALD C. JACKSON.
C. A. ADAMS.

REPRESENTATIVES ON BOARD OF AWARD OF THE JOHN FRITZ MEDAL.

JOHN W. LIEB, JR.
SCHUYLER SKAATS WHEELER.
SAMUEL SHELDON.
HENRY G. STOTT.

REPRESENTATIVES, BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

JOHN W. LIEB, JR., New York.
SAMUEL SHELDON, Brooklyn, N. Y.
HENRY G. STOTT, New York,

REPRESENTATIVES ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SAMUEL SHELDON, Brooklyn, N. Y.
PERCY H. THOMAS, New York.

THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

United States National Committee.

ELIHU THOMSON, President, Lynn, Mass.
CHARLES F. SCOTT, 1st Vice-president.
SAMUEL SHELDON, 2d Vice-president.
ARTHUR E. KENNELLY, Secretary,
Harvard University, Cambridge, Mass.
BION J. ARNOLD.
B. A. BEHREND.
A. W. BERRESFORD.
JOHN J. CARTY.
W. C. L. EGLIN.
CARL HERING.
JOHN W. HOWELL.
DUGALD C. JACKSON.
FRANCIS W. JONES.
BENJAMIN G. LAMME.
W. A. LAYMAN.
JOHN W. LIEB, JR.
CLAYTON H. SHARP.
CHARLES P. STEINMETZ.
LEWIS B. STILLWELL.
HENRY G. STOTT.
SAMUEL W. STRATTON.

Local Honorary Secretaries

JAMES S. FITZMAURICE,
210 George St., Sydney, N. S. W.

H. F. PARSHALL,
Salisbury House, London Wall E. C., London.

ROBERT B. OWENS,
McGill University, Montreal, P. Q.

WILLIAM B. HALE,
Cadena 10, City of Mexico.

W. G. T. GOODMAN,
Adelaide, South Australia.

ROBERT J SCOTT
Christ Church, New Zealand.

HENRY GRAFTIC
St. Petersburg, Russia.

Sections and Branches—Directory.

SECTIONS	Organization authorized by Board of Directors	Chairman	Secretary
Atlanta	Jan. 19, '04	J. H. Finney	G. J. Yundt, Southern Bell Tel. Co., Atlanta, Ga.
Baltimore	Dec. 16, '04	J. B. Whitehead	C. G. Edwards, City Hall, Baltimore, Md.
Boston	Feb. 13, '03	A. E. Kennelly	A. L. Pearson, 93 Federal St., Boston, Mass.
Chicago	1893	H. R. King	J. G. Wray, 203 Washington St., Chicago, Ill.
Cincinnati	Dec. 17, '02	A. G. Wessling	
Cleveland	Sept. 27, '07	C. W. Ricker	F. M. Hibben, 1549 Winton Ave., Cleveland, O.
Columbus	Dec. 20, '03	R. J. Feather	H. L. Bachman, 1070 E. Fulton St., Columbus, O.
Fort Wayne	Aug. 14, '08	E. A. Wagner	J. V. Hunter, 506 W. Jefferson St., Ft. Wayne, Ind.
Ithaca	Oct. 15, '02	E. L. Nichols	H. H. Norris, Cornell Univ., Ithaca, N. Y.
Los Angeles	May 19, '08	C. W. Koiner	J. E. MacDonald, 444 P. E. Bldg., Los Angeles, Cal.
Mexico	Dec. 13, '07	R. F. Hayward	F. D. Nims, Mex. Lt. & Pr. Co., Mexico, Mex.
Minnesota	Apr. 7, '02	E. H. Scofield	A. L. Abbott, 185 E. 4th St., St. Paul, Minn.
Norfolk	Mar. 13, '08	D. G. Stanbrough	R. R. Grant, P. O. Box 254, Norfolk, Va.
Philadelphia	Feb. 18, '03;	Paul Spencer	H. F. Sanville, 1708 Sansom St., Phila., Pa.
Pittsburg	Oct. 13, '02	W. Edgar Reed	B. P. Rowe, 911 Ramsey Ave., Wilkinsburg, Pa.
Pittsfield	Mar. 25, '04	W. A. Hall	H. W. Tobey, General Electric Co., Pittsfield, Mass.
San Francisco	Dec. 23, '04	A. M. Hunt,	G. R. Murphy, 2699 Union St., San Francisco, Cal.
Schenectady	Jan. 26, '03	E. J. Berg	M. O. Troy, G. E. Co., Schenectady, N. Y.
Seattle	Jan. 19, '04	J. H. Harisberger	Geo. H. Moore, 816 Terry Ave., Seattle, Wash.
St. Louis	Jan. 14, '03	A. S. Langsdorf	H. I. Finch, 5228 Kensington Ave., St. Louis, Mo,
Toledo	June 3, '07	C. R. McKay	Geo. E. Kirk, 1614 The Nichols, Toledo, O.
Toronto	Sept. 30, '03	W. A. Bucke	W. G. Chace, 124 Confed. Life Bldg., Toronto, Can.
Urbana	Nov. 25, '02	E. B. Paine	E. J. Wenger, 911 W. California St., Urbana, Ill.
Washington, D. C	Apr. 9, '03	Philander Betts	H. C. Eddy, 806 Westory Building, Washington, D. C.

Sections and Branches—Directory.

BRANCHES	Organization authorized by Board of Directors	Chairman	Secretary
Arkansas, Univ. of	Mar. 25, '04	C. R. Rhodes	F. S. White, 523 North Willow St., Fayetteville, Ark.
Armour Institute	Feb. 26, '04	T. W. Simpson	J. E. Snow, Armour Inst. Tech., Chicago, Ill.
Cincinnati. Univ. of	Apr. 10, '08	C. R. Wylie	C. A. Winder, 1332 Lincoln Ave., Cincinnati, O.
Colorado, Univ. of	Dec. 16, '04	H. H. Watters	L. D. Jones, Univ. of Colorado, Boulder, Colo.
Iowa State College	Apr. 15, '03	F. A. Fish	Adolph Shane, Iowa State College, Ames, Ia.
Kansas State Agr. Col.	Jan. 10, '08	W. L. Enfield	W. C. Lane, Kan. State Agr. Col., Manhattan, Kan
Kansas, Univ. of	Mar. 18, '08	Ray Jones	E. J. Thiele, 1042 Tennessee Street, Lawrence, Kan.
Lehigh University	Oct. 15, '02	A. S. Garrison	R. F. Turner Lehigh Univ., Bethlehem, Pa.
Lewis Institute	Nov. 8, '07	W. H. Hayes	P. B. Woodworth, Lewis Institute, Chicago, Ill.
Maine, Univ. of	Dec. 26, '06		Gustav Wittig, Univ. of Maine, Orono, Me.
Michigan Univ. of	Mar. 25, '04	C. M. Davis	H. F. Baxter, 556 S. State St., Ann Arbor, Mich.
Missouri, Univ. of	Jan. 10, '03	H. B. Shaw	H. D. Carpenter, Univ. of Missouri, Columbia, Mo.
Montana Agr. Col.	May 21, '07	B. S. Hind	J. A. Thaler, Montana Agr. Col., Bozeman, Mont.
Nebraska, Univ. of	Apr. 10, '08	Geo. H. Morse	L. E. Hurtz, Lincoln Tel. Co., Lincoln, Neb.
Ohio State Univ	Dec. 20, '02	F. W. Funk	F. C. Caldwell, Ohio State Univ., Columbus O.
Oregon State Agr. Col.	Mar. 24, '08	S. H. Graf	C. Christiansen State Agricultural College, Corvallis, Ore.
Penn. State College	Dec. 20, '02	D. R. Simpson	C. D. Preston, Penn. State College, Pa.
Purdue Univ	Jan. 26, '03	J. W. Esterline	H. T. Plumb, Purdue Univ., Lafayette, Ind.
Stanford Univ	Dec. 13, '07	W. C. North	A. J. Gowan, Stanford Univ., California.
Syracuse Univ	Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse Univ., Syracuse, N. Y.
Texas, Univ. of	Feb. 14, '08	A. C. Scott	B. E. Kenyon, Univ. of Texas, Austin, Tex.
Wash. State Col. of	Dec. 13, '07	H. V. Carpenter	M. K. Akers, State Col. of Wash., Pullman, Wash.
Washington Univ	Feb. 26, '04	C. M. Duncan	H. F. Thomson, 5011 Washington Ave., St. Louis, Mo
Wisconsin, Univ. of	Oct. 15, '02	C. E. Carter	J. W. Shuster, Univ. of Wisconsin, Madison, Wis.
Worcester Poly. Inst.	Mar. 25, '04	F. A. Spencer	W. D. Stearns Worcester Poly. Inst., Worcester, Mass.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29–July 2, 1908.

Copyright 1908. By A.I.E.E.
(*Subject to final revision for the Transactions.*)

THE GENERAL EQUATIONS OF THE ELECTRIC CIRCUIT

BY CHARLES P. STEINMETZ

Introduction. The following investigation of the general equations of the electric circuit was carried out during the last year, and necessarily is still very incomplete, and in some instances may require modification. As, however, our incomplete knowledge of the phenomena resulting from the stored energy of the electric field is at present the main hindrance to a practically unlimited extension of high potential transmission and distribution, the study of these phenomena represents the most important problem of electrical engineering, and the following outline is given in the hope of inducing other investigators to take up and continue the study of the subject.

As in all theoretical investigations, the most important part is the practical interpretation of the mathematical equations. Some such interpretations have been attempted throughout the following and may be read even without following the equations from which they are derived.

This paper represents an attempt to investigate mathematically the phenomena which may occur in the most general case of an electric circuit.

The general equations of the electric circuit, *i.e.*, equations which represent current and voltage in any circuit or circuit section irrespective of the character of power, voltage etc., can be derived under the condition that the constants of the electric circuit: resistance, inductance, conductance, and capacity are constant.

These equations are given by a sum of terms or groups containing trigonometrical and exponential functions of time and distance, and the differences between all the phenomena which may occur in electric circuits merely result from different numerical values of the integration constants of this general equation.

Each group or term comprises four waves of the same frequency—two propagate in the one, the other two in the opposite direction—and can be considered as comprising two component waves, each consisting of a wave and its reflected wave, or return wave.

One of the component waves increases in the direction of propagation, the other decreases. The former, however, decreases with the time more rapidly than the latter.

A standing wave is a wave in which the component waves coincide. A standing wave has the same intensity throughout the circuit. It starts at maximum value and dies out with the time at a rate corresponding to the dissipation of energy in the circuit, as given by the time constant of the circuit.

The general wave, comprising two component waves (each consisting of main wave and return wave), gradually builds up to a maximum and then dies out again. One of the component waves dies out slower, the other faster than corresponds to the energy dissipation in the circuit, and the former decreases while the latter increases with the distance.

A free oscillation of a circuit is a wave in which no energy is supplied to or abstracted from the circuit.

The free oscillation of a uniform circuit is a standing wave, but a standing wave is not necessarily a free oscillation.

The electric wave in a uniform circuit is oscillatory in time if its frequency is high and the circuit of moderate length. With very low frequency or extreme length, as in submarine cables, or long distance telephone lines, waves may occur which are not oscillatory, but logarithmic.

In overhead transmission lines and underground cable systems all phenomena which may result in excessive voltages or currents are oscillatory in nature.

In a traveling wave each component wave traverses the circuit at constant velocity and wave shape, and an amplitude which decreases with the distance traveled, but at any point rises from zero to a maximum, and then gradually decreases again to zero. It is not a free oscillation, but energy is transferred along the circuit by it.

The phenomena of alternating currents are those of a general wave in which the time decrement of the first component wave vanishes, that is, the energy transfer constant f equals the time constant w.

In a complex circuit, that is, circuit containing a number of sections of different constants, the same general equation can be extended throughout the entire circuit and across the transition points between different sections of the circuit of different constants, by using as distance variable the velocity of propagation of the wave in each section of the circuit.

The free oscillation of a complex circuit is not a standing wave, and the equations of the standing wave do not apply to it, but is a general wave in which the intensity of the wave increases or decreases with the distance in each section, and energy transfer occurs between the different sections of the circuit.

The free oscillation of a complex circuit dies out at a rate given by the mean time decrement, or mean time constant of the entire circuit.

Those sections having an individual time constant greater than the mean time constant of the entire circuit receive energy from the adjoining sections, while those sections having an individual time constant less than the mean time constant of the entire circuit supply energy to the rest of the circuit during a free oscillation.

During a free oscillation of a complex circuit each section of the circuit does not perform a free oscillation.

In a section of high energy dissipation, as a transmission line, the oscillation may last very much longer, and be of lower frequency, if this section is a part of a complex oscillating circuit, than if the section oscillates alone.

In the free oscillation of a complex circuit the entire length of the circuit, when expressed in velocity measure, represents a complete wave, or a half wave, or a quarter wave, or a multiple thereof.

In the free oscillation of a complex circuit the energy of the electric field of each section divides between the energy dissipated in the section and the energy transferred to other sections (or received) in a proportion depending upon the circuit constants.

At a transition point between sections of a complex circuit, the general equations remain the same when expressed with the propagation velocity as distance unit, but the numerical values of the integration constants change.

At a transition point between sections of a complex circuit transformation of current and voltage, reflection and refraction occurs.

A single wave at a transition point is partly reflected, partly transmitted, but without change of phase angle, that is, the reflected and the transmitted wave have at the transition point the same phase angle as the incident wave.

A single wave at a transition point divides between transmitted and reflected wave in a proportion depending upon the circuit constants.

The greater the change of constants at the transition point, the greater is the reflected and less the transmitted wave.

In a general wave, at a transition point, a transformation of current and voltage occurs by a ratio proportional to the circuit constant $\sqrt{\frac{L}{C}}$.

When traversing a transition point a refraction occurs, so that the ratio of the tangents of the distance phase angle of the wave at the two sides of the transition point is constant and equal to the voltage transformation ratio.

I. DERIVATION OF GENERAL EQUATIONS

1. The energy relations of an electric circuit are characterized by the four constants:

r = effective resistance, representing the power consumption depending upon the current, $i^2 r$, or the energy voltage, $i r$, consumed in the circuit.

L = effective inductance, representing the energy storage depending upon the current, $\frac{i^2 L}{2}$, as electromagnetic component, $i L$, of the electric field; or the voltage induced by a change of the current, $L \frac{d i}{d t}$.

g = effective shunted conductance, representing the power consumption depending upon the voltage, $e^2 g$, or the energy current, $e g$, consumed in the circuit.

C = effective capacity, representing the energy storage depending upon the voltage, $\frac{e^2 C}{2}$, as electrostatic component, $e C$, of the electric field, or the current consumed by a change of the voltage, $C \frac{de}{dt}$.

As every circuit element consumes and stores energy, and so contains all four circuit constants, the assumption usually made in the investigation of electric circuits, that these four constants r, L, g, C, are localized, is permissible only in cases dealing with the usual phenomena of direct and of alternating currents, but fails when dealing with the transient phenomena resulting from the readjustment of the circuit to changes of circuit conditions, to external influences such as lightning, or when investigating high frequency phenomena, voltage and current distribution in long distance high potential circuits, cables, telephone lines, etc., and r, L, g, C, must then be treated as distributed throughout the circuit.

As r, L, g, C, are denoted the effective resistance, inductance, conductance, and capacity, per unit length of circuit, choosing as unit of length of the circuit whatever may be suitable, a centimeter in the high frequency oscillation over the multigap lightning-arrester circuit, or a mile in a long distance transmission circuit, or high potential cable.

In the most general case of an electric circuit or circuit section, it is possible to derive from the constants of the circuit, r, L, g, C, and without any assumption whatever regarding current, voltage, etc., general equations of the electric circuit, and some results and conclusions from such equations, which are based on the single assumption, that the constants r, L, g, C, remain constant with the time, t, and distance, u; *i.e.*, are the same for every unit length of the circuit or section of the circuit to which the equations apply. Where the circuit constants change, as where another circuit joins it, the integration constants in the equations also change correspondingly.

Special cases of these general equations then are all the phenomena of direct currents, alternating currents, discharges of reactive coils, high frequency oscillations, traveling waves, etc., and the differences between these different circuits are due merely to different values of the integration constants.

2. In a circuit, or a section of a circuit, containing distributed resistance, inductance, conductance, and capacity, as a transmission line, cable, high potential coil of transformer, telephone or telegraph circuit, etc., let:

r = effective resistance, per unit length of circuit.
L = effective inductance, per unit length of circuit.
g = effective shunted conductance, per unit length of circuit.
C = effective capacity, per unit length of circuit.

Let the time be denoted by t, and the distance from some starting point by u.

Let e = voltage, and i = current, at any point u and at any time t.

e and i are functions of time t and distance u.

For any element $d\,u$ of the circuit, the differential equations then apply:

$$\frac{d\,e}{d\,u} = r\,i + L\,\frac{d\,i}{d\,t} \qquad (1)$$

$$\frac{d\,i}{d\,u} = g\,e + C\,\frac{d\,e}{d\,t} \qquad (2)$$

Differentiating (1) after t, and (2) after u, and substituting (1) into (2), gives:

$$\frac{d^2\,i}{d\,u^2} = r\,g\,i + (r\,C + g\,L)\,\frac{d\,i}{d\,t} + L\,C\,\frac{d^2\,i}{d\,t^2} \qquad (3)$$

and in the same manner:

$$\frac{d^2\,e}{d\,u^2} = r\,g\,e + (r\,C + g\,L)\,\frac{d\,e}{d\,t} + L\,C\,\frac{d^2\,e}{d\,t^2} \qquad (4)$$

These differential equations, of second order, of current i and voltage e, are identical. That is:

In an electric circuit, current and electromotive force are represented by the same equations, differing by the integration constants only, which are derived from the terminal conditions of the problem.

Equation (3) is integrated by terms of the form:

$$i = A\,\varepsilon^{-vu-st} \qquad (5)$$

Substituting (5) in (3) gives the identity:

$$\begin{aligned} v^2 &= r\,g - (r\,C + g\,L)\,s + L\,C\,s^2 \\ &= (s\,L - r)\,(s\,C - g) \qquad (6) \end{aligned}$$

In the terms of the form (5), the relation (6) must exist between the coefficients of u and t.

Substituting (6) into (1) gives:

$$\frac{d\,e}{d\,u} = (r - s\,L)\,A\,\varepsilon^{-vu-st} \tag{7}$$

and, integrated:

$$e = \frac{s\,L - r}{v}\,A\,\varepsilon^{-vu-st} \tag{8}$$

In their most general form, the *Equations of the Electric Circuit* are:

$$i = \sum\nolimits^{n} \left\{ A_n\,\varepsilon^{-v_n u - s_n t} \right\} \tag{9}$$

$$e = \sum\nolimits^{n} \left\{ \frac{s_n\,L - r}{v_n}\,A_n\,\varepsilon^{-v_n u - s_n t} \right\} \tag{10}$$

$$v_n^2 = (s_n\,L - r)\,(s_n\,C - g) = 0 \tag{11}$$

where A_n, v_n, and s_n, are integration constants, the latter two being related to each other by the equation (11).

3. These pairs of integration constants: A_n, v_n and s_n, are determinated by the terminal conditions of the problem, as the current and voltage at fixed points of the circuit as function of time, or the distribution of current and voltage at a fixed time as function of the distance, etc.

While i and e must always be real quantities; v_n and s_n as exponents may be complex quantities, and in this case, the integration constants, A_n, are such complex quantities, that by combining the different exponential terms of the same index n, the imaginary terms in A_n and $\frac{s_n\,L - r}{v_n}\,A_n$ cancel.

Denoting, in the exponential function:

$$\varepsilon^{-vu-st}$$

$$v = h + j\,k$$
$$s = p + j\,q \tag{12}$$

it is:

$$\varepsilon^{-vu-st} = \varepsilon^{-hu-pt}\quad \varepsilon^{-j(ku+qt)}$$

and the latter term resolves into trigonometric functions of the angle:

$$k\,u + q\,t$$

$$k\,u + q\,t = \text{constant} \tag{13}$$

so gives the relation between u and t for constant phase of the oscillation or alternation of the current or voltage.

With change of time t, the phase changes in position u, in the circuit, *i.e.*, moves along the circuit, and the velocity of this motion is given by differentiating (13) after t as

$$V = \frac{d\,u}{d\,t} = -\frac{q}{k} \tag{14}$$

that is:

$$V = -\frac{q}{k} \tag{15}$$

is the velocity of *propagation of the electric phenomena in the circuit.*

(If no energy losses occur, $r = 0$, $g = 0$, in a straight conductor in a medium of unit magnetic and dielectric constant, that is, unit permeability and unit inductive capacity; V is the velocity of light.)

4. Since (11) is a quadratic equation, several pairs or corresponding values of v and s exist, which correspond to the same equation (11), and can be combined with each other into a group.

Such a group of terms, of the same index n is defined by the equation (11):

$$v^2 = (s\,L - r)\,(s\,C - g) \tag{16}$$

and substituting:

$$v = v_1 \sqrt{L\,C} \tag{17}$$

and also:

$$\begin{aligned} v &= h + j\,k \\ v_1 &= h_1 + j\,k_1 \\ s &= p + j\,q \end{aligned} \tag{18}$$

Hence:

$$\begin{aligned} h &= h_1 \sqrt{LC} \\ k &= k_1 \sqrt{LC} \end{aligned} \qquad (19)$$

it is, substituting (18) in (16):

$$(h_1 + j\,k_1)^2 = \left[(p + j\,q) - \frac{r}{L}\right] \left[(p + j\,q) - \frac{g}{C}\right] \qquad (20)$$

resolved, and substituting:

$$w = \tfrac{1}{2}\left(\frac{r}{L} + \frac{g}{C}\right) \qquad (21)$$

$$m = \tfrac{1}{2}\left(\frac{r}{L} - \frac{g}{C}\right) \qquad (22)$$

$$p = f + w \qquad (23)$$

gives:

$$\left.\begin{aligned} h_1^2 - k_1^2 &= f^2 - q^2 - m^2 \\ h_1\,k_1 &= f\,q \end{aligned}\right\} \qquad (24)$$

and:

$$\left.\begin{aligned} f^2 - q^2 &= h_1^2 - k_1^2 + m^2 \\ f\,q &= h_1\,k_1 \end{aligned}\right\} \qquad (25)$$

hence:

$$\left.\begin{aligned} h &= \sqrt{LC}\sqrt{\tfrac{1}{2}\left\{R_1^2 + f^2 - q^2 - m^2\right\}} \\ k &= \sqrt{LC}\sqrt{\tfrac{1}{2}\left\{R_1^2 - f^2 + q^2 + m^2\right\}} \\ R_1^2 &= \sqrt{(f^2 + q^2 - m^2)^2 + 4\,q^2\,m^2} = \frac{h^2 + k^2}{LC} \end{aligned}\right\} \qquad (26)$$

or:

$$\left.\begin{aligned} f &= \frac{1}{\sqrt{LC}}\sqrt{\tfrac{1}{2}\left\{R_2^2 + h^2 - k^2 + LC\,m^2\right\}} \\ q &= \frac{1}{\sqrt{LC}}\sqrt{\tfrac{1}{2}\left\{R_2^2 - h^2 + k^2 - LC\,m^2\right\}} \end{aligned}\right\} \qquad (27)$$

$$R_2^2 = \sqrt{(h^2+k^2+L\,C\,m^2)^2 - 4\,L\,C\,k^2\,m^2} = \overline{L\,C\,(f^2+q^2)}$$

This gives eight pairs of corresponding values of v and s:

$$\left.\begin{array}{lll}
1. & v = +h+j\,k & s = w-f-j\,q \\
 & +h-j\,k & w-f+j\,q \\
2. & v = -h-j\,k & s = w-f-j\,q \\
 & -h+j\,k & w-f+j\,q \\
3. & v = -h+j\,k & s = w+f-j\,q \\
 & -h-j\,k & w+f+j\,q \\
4. & v = +h-j\,k & s = w+f-j\,q \\
 & +h+j\,k & w+f+j\,q
\end{array}\right\} \quad (28)$$

Substituting these values in the general equations (9) and (10), and in the usual manner transforming the exponential functions of imaginary exponents, into trigonometric functions, and substituting for the integration constants, A, the new constants:

$$C = A + A'$$

$$C' = j\,(A - A')$$

then gives as the general expression of the

Equations of the Electric Circuit:

$$\begin{aligned}
i = \Sigma[&\varepsilon^{-hu-(w-f)t}\,\{C_1 \cos(qt-ku) + C_1' \sin(qt-ku)\} && (i_1) \\
&-\varepsilon^{+hu-(w-f)t}\,\{C_2 \cos(qt+ku) + C_2' \sin(qt+ku)\} && (i_2) \\
&+\varepsilon^{+hu-(w+f)t}\,\{C_3 \cos(qt-ku) + C_3' \sin(qt-ku)\} && (i_3) \\
&-\varepsilon^{-hu-(w+f)t}\,\{C_4 \cos(qt+ku) + C_4' \sin(qt+ku)\}] && (i_4)
\end{aligned} \qquad (29)$$

$$\begin{aligned}
e = \Sigma[&\varepsilon^{-hu-(w-f)t}\,\{(c_1'\,C_1' - c_1\,C_1)\cos(qt-ku) - (c_1'\,C_1 + c_1\,C_1') \\
&\qquad \sin(qt-ku)\} && (e_1) \\
&+\varepsilon^{+hu-(w-f)t}\,\{(c_1'\,C_2' - c_1\,C_2)\cos(qt+ku) - (c_1'\,C_2 + c_1\,C_2') \\
&\qquad \sin(qt+ku)\} && (e_2) \\
&+\varepsilon^{+hu-(w+f)t}\,\{(c_2'\,C_3' - c_2\,C_3)\cos(qt-ku) - (c_2'\,C_3 + c_2\,C_3') \\
&\qquad \sin(qt-ku)\} && (e_3)
\end{aligned} \qquad (30)$$

$$+\varepsilon^{-hu-(w+f)t}\left\{(c_2' C_4' - c_2 C_4)\cos(qt+ku) - (c_2' C_4 + c_2 C_4')\sin(qt+ku)\right\}\Big] \qquad (e_4)$$

where C_1, C_1', C_2, C_2', C_3, C_3', C_4, C_4', and two of the four values, f, q, h, k, are integration constants, depending on the terminal conditions, and:

$$\left.\begin{aligned}
c_1 &= \frac{q\,k + h\,(m+f)}{h^2+k^2}\,L \\
c_1' &= \frac{k\,(m+f) - q\,h}{h^2+k^2}\,L \\
c_2 &= \frac{q\,k - h\,(m-f)}{h^2+k^2}\,L \\
c_2' &= \frac{k\,(m-f) + q\,h}{h^2+k^2}\,L
\end{aligned}\right\} \qquad (31)$$

and:

$$\left.\begin{aligned}
w &= \tfrac{1}{2}\left(\frac{r}{L}+\frac{g}{C}\right) \\
m &= \tfrac{1}{2}\left(\frac{r}{L}-\frac{g}{C}\right)
\end{aligned}\right\} \qquad (32)$$

and h, k, and f, q, are related by the equations:

$$\left.\begin{aligned}
h &= \sqrt{L\,C}\,\sqrt{\tfrac{1}{2}\,\{R_1^2+f^2-q^2-m^2\}} \\
k &= \sqrt{L\,C}\,\sqrt{\tfrac{1}{2}\,\{R_1^2-f^2+q^2+m^2\}} \\
R_1^2 &= \sqrt{(f^2+q^2-m^2)^2+4\,q^2\,m^2}
\end{aligned}\right\} \qquad (33)$$

hence:

$$h^2+k^2 = L\,C\,R_1^2 \qquad (34)$$

or:

$$\left.\begin{aligned}
f &= \frac{1}{\sqrt{LC}}\sqrt{\tfrac{1}{2}\,\{R_2^2+h^2-k^2+L\,C\,m^2\}} \\
q &= \frac{1}{\sqrt{LC}}\sqrt{\tfrac{1}{2}\,\{R_2^2-h^2+k^2-L\,C\,m^2\}} \\
R_2^2 &= \sqrt{(h^2+k^2+L\,C\,m^2)^2-4\,L\,C\,k^2\,m^2}
\end{aligned}\right\} \qquad (35)$$

hence

$$f^2 + q^2 = \frac{R_2^2}{L\,C} \qquad (36)$$

II. Discussion of General Equations.

5. The general equations of current and voltage of a circuit or section of circuit having uniformly distributed and constant values of r, L, g, C, appear as a sum of groups of four terms each, characterized by the feature, that the four terms of each group have the same values of f, q, h, k.

Of the four terms of each group, i_1, i_2, i_3 i_4, or e_1, e_2, e_3, e_4, respectively (equations (29) and (30)), two contain the angles $(qt - ku)$; i_1, e_1, and i_3, e_3; and two contain the angles $(qt + ku)$; i_2, e_2, and i_4, e_4.

In the former, the velocity of propagation is:

$$\frac{d\,u}{d\,t} = + \frac{q}{k}$$

hence positive, that is, towards raising u.

In the latter, the velocity of propagation is:

$$\frac{d\,u}{d\,t} = - \frac{q}{k}$$

or negative, that is, towards decreasing u.

Each group consists of two waves and their reflected waves.

$i' = i_1 - i_2$ and $e' = e_1 + e_2$ is the first wave and its reflected wave, and

$i'' = i_3 - i_4$ and $e'' = e_3 + e_4$ is the second wave and its reflected wave.

In the first wave, i', e', the amplitude decreases in the direction of propagation, ε^{-hu} for rising, ε^{+hu} for decreasing u, and the wave dies out with increasing time t, by $\varepsilon^{-(w-f)} = \varepsilon^{-wt}\,\varepsilon^{+ft}$.

In the second wave, i'', e'', the amplitude increases in the direction of propagation, ε^{+hu} for rising, ε^{-hu} for decreasing u, but the wave dies out with the increasing time t, by $\varepsilon^{-(w+f)t} = \varepsilon^{-wt}\,\varepsilon^{-ft}$, that is, faster than the first wave.

If the amplitude of the wave remained constant throughout the circuit—as would be the case in a free oscillation of the circuit, in which the stored energy of the circuit is dissipated, but no power transferred one way or the other—that is, if $h=0$, it also is, by (56), $f=0$, that is, both waves coincide into one, which dies out with the time by the decrement ε^{-wt}.

It thus follows:

In general, two waves, with their reflected waves, traverse the circuit, of which the one i'', e'', increases in amplitude in the direction of propagation, but dies out correspondingly more rapidly in time, that is, faster than a wave of constant amplitude; while the other i', e', decreases in amplitude, but lasts a longer time, that is, dies out slower than a wave of constant amplitude. That is, in the one wave, i'', e'', a decrease of amplitude takes place at a sacrifice of duration in time, while in the other wave, i', e', a slower dying out of the wave with the time is produced at the expense of a decrease of amplitude during its propagation.

It is seen herefrom, that the equations usually given for an oscillating circuit, which do not contain an exponential function of the distance, are not the most general equations, but correspond only to the special case of a free oscillation in which no energy transfer takes place, and so do not apply to the traveling wave or impulse, nor to the oscillation of a complex circuit.

6. In the equations (29) and (30):

$$q\,t = 2\,\pi$$

gives the time of a complete cycle, that is, the *period of the wave*:

$$T = \frac{2\pi}{q}$$

and:

$$N = \frac{q}{2\pi}$$

the frequency of the wave.

$$k\,u = 2\,\pi$$

gives the distance of a complete cycle, that is, the *wave length*:

$$U = \frac{2\pi}{k}$$

$$(w - f)\,t = 1 \text{ and}$$
$$(w + f)\,t = 1$$

gives the time:

$$T_1' = \frac{1}{w - f} \text{ and}$$

$$T_1'' = \frac{1}{w + f}$$

during which the wave decreases to $1/\varepsilon = .3679$ of its value, and

$$h\, u = 1$$

gives the distance:

$$U_1 = 1/h$$

over which the wave decreases to $1/\varepsilon = .3679$ of its value.

That is:

q is the *frequency constant* of the wave:
k is the *wave length constant*:
$(w - f)$ and $(w + f)$ are the *time attenuation constants* of the wave:
h is the *distance attenuation constant* of the wave:

7. If the frequency of the current and voltage is very high, thousands of cycles and more, as with traveling waves, lightning disturbances, high frequency oscillations, etc., q is a very large quantity compared with f, w, m, h, k, and k is a large quantity compared with h, and, by dropping terms of secondary order, the preceding equations can be simplified, and become:

$$\left.\begin{aligned} h &= f \sqrt{L\,C} \\ k &= q \sqrt{L\,C} \end{aligned}\right\} \quad (37)$$

and:

$$\left.\begin{aligned} c_1 = c_2 &= \sqrt{\frac{L}{C}} \\ c_1' = c_2' &= \frac{m}{q} \sqrt{\frac{L}{C}} = 0 \end{aligned}\right\} \quad (38)$$

Denoting:

$$\left.\begin{aligned} \sigma &= \sqrt{L\,C} \\ c &= \sqrt{\frac{L}{C}} \end{aligned}\right\} \quad (39)$$

where σ is the reciprocal of the frequency of propagation (velocity of light), it is:

$$\left.\begin{aligned} h &= \sigma f \\ k &= \sigma q \end{aligned}\right\} \quad (40)$$

$$\left.\begin{aligned} c_1 &= c_2 = c \\ c_1' &= c_2' = \frac{m}{q} c = 0 \end{aligned}\right\} \quad (41)$$

and, introducing the new independent variable, as distance:

$$\lambda = \sigma u \quad (42)$$

it is:

$$\left.\begin{aligned} k u &= q \lambda \\ h u &= f \lambda \end{aligned}\right\} \quad (43)$$

hence, the wave length is given by:

$$q \lambda = 2 \pi$$

as:

$$\lambda_0 = \frac{2\pi}{q} \quad (44)$$

and since the period is:

$$T_0 = \frac{2\pi}{q}$$

it follows, that by the introduction of the denotation (42), distances are measured with the velocity of propagation as unit length, and wave length U and period T have the same numerical values.

Substituting now in equations (29) and (30), gives:

$$\begin{aligned} i = \varepsilon^{-wt} \Sigma \{ & \varepsilon^{+f(t-\lambda)} D_1 [q\,(t-\lambda)] - \varepsilon^{+f(t+\lambda)} D_2 [q\,(t+\lambda)] \quad (i') \\ & + \varepsilon^{-f(t-\lambda)} D_3 [q\,(t-\lambda)] - \varepsilon^{-f(t+\lambda)} D_4 [q\,(t+\lambda)] \} \quad (i'') \end{aligned} \quad (45)$$

$$\begin{aligned} e = \sqrt{\frac{L}{C}}\, \varepsilon^{-wt} \Sigma \{ & \varepsilon^{+f(t-\lambda)} D_1 [q\,(t-\lambda)] + \varepsilon^{+f(t+\lambda)} D_2 [q\,(t+\lambda)] \quad (e') \\ & + \varepsilon^{-f(t-\lambda)} D_3 [q\,(t-\lambda)] + \varepsilon^{-f(t+\lambda)} D_4 [q\,(t+\lambda)] \} \quad (e'') \end{aligned} \quad (46)$$

where:

$$D[q(t \pm \lambda)] = C \cos q(t \pm \lambda) + C' \sin q(t \pm \lambda) \qquad (47)$$

8. As seen from equations (45) and (46), the waves are products of ε^{-wt} and a function of $(t-\lambda)$ for the main wave, $(t+\lambda)$ for the reflected wave:

$$\left.\begin{aligned} i_1+i_3 &= \varepsilon^{-wt} f_1(t-\lambda) \\ i_2+i_4 &= \varepsilon^{-wt} f_2(t+\lambda) \end{aligned}\right\} \qquad (48)$$

Hence, for constant $(t-\lambda)$ on the main waves, and for constant $(t+\lambda)$ on the reflected waves, it is:

$$\left.\begin{aligned} i_1+i_3 &= B\ \varepsilon^{-wt} \\ i_2+i_4 &= B'\, \varepsilon^{-wt} \end{aligned}\right\} \qquad (49)$$

That is, during its passage along the circuit, the wave decreases by the decrement ε^{-wt}, or at a constant rate, independent of frequency, wave length, etc., and depending merely on the circuit constants r, L, g, C.

That is, the decrement of the traveling wave in the direction of its mótion is independent of the character of the wave, as its frequency, etc.

In other words, an impulse traveling along the circuit retains its wave shape, provided that r, L, g, C, are constant.

If r and g increase with the frequency, as is often the case, the higher frequency waves die out faster, and the wave shape gradually smooths out in the direction of travel.

The physical meaning of the two waves i' and e'' can best be appreciated by observing the effect of the wave when traversing a fixed point λ of the circuit.

Consider as instance the main wave only; $i' = i_1 + i_3$; the same applies for the reflected wave.

Assuming then, that at time $t=0$, the current $I'=0$, it is, for constant λ:

$$I = D\left(\varepsilon^{-(w-f)t} - \varepsilon^{-(w+f)t}\right)$$

the amplitude of current I at point λ.

As this is the difference of two exponential functions of different decrement, it follows, that as function of time t, I' rises from 0 to a maximum and then decreases again to zero, as shown in Fig. 1, and the actual current i is the oscillatory wave with I as envelope.

The combination of the two waves thus represents the passage of a wave across a given point, the amplitude rising during the arrival, and decreasing again after the passage of the wave.

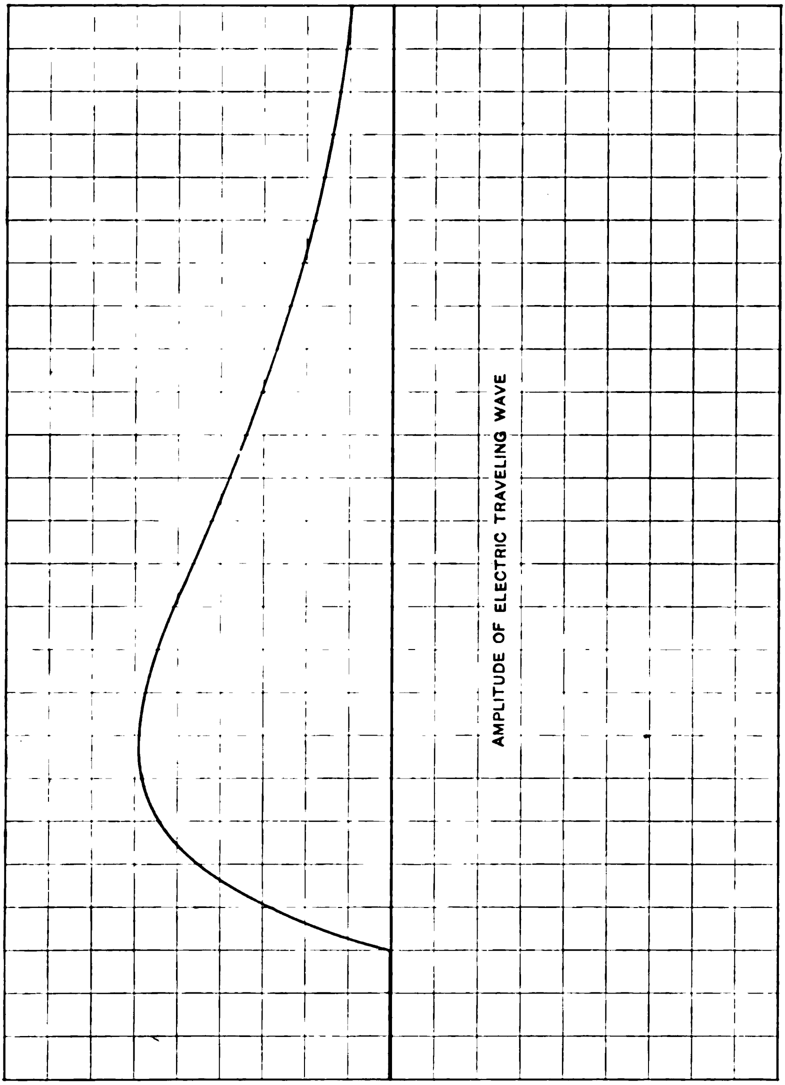


Fig. 1

9. If h and also f equal zero, i', e', and i'', e'', coincide in

equations (45) and (46), and the equations (45) (46) assume the form:

$$i = \varepsilon^{-wt} \Sigma \{[B_1 \cos q (t - \lambda) + B_1' \sin q (t - \lambda)] - [B_2 \cos q (t + \lambda) + B_2' \sin q (t + \lambda)]\} \qquad (50)$$

$$e = \sqrt{\frac{L}{C}}\, \varepsilon^{-wt} \Sigma \{[B_1 \cos q (t - \lambda) + B_1' \sin q (t - \lambda)] + [B_2 \cos q (t + \lambda) + B_2' \sin q (t + \lambda)]\} \qquad (51)$$

These equations contain the distance λ only in the trigonometric, but not in the exponential function, that is, i and e vary in phase throughout the circuit, but not in amplitude, or in other words, the oscillation is of uniform intensity throughout the circuit, dying out uniformly with the time, from an initial maximum value, but the wave does not travel along the circuit, but is a stationary or standing wave. It is an oscillatory discharge of a circuit containing a distributed r, L, g, C, and so analogous to the oscillating condenser discharge through an inductive circuit, except that, due to the distributed capacity, the phase changes along the circuit. The free oscillations of a uniform circuit, as a transmission line, are of this character.

For $\lambda = 0$, that is, assuming the wave length of the oscillation is so great, hence the circuit as such a small fraction of the wave length, that the phase of i and e can be assumed as uniform throughout the circuit, the equations (50) and (51) assume the form:

$$i = \varepsilon^{-wt} \{B_0 \cos q t - B_0' \sin q t\}$$

$$e = \sqrt{\frac{L}{C}}\, \varepsilon^{-wt} \{B_0 \cos q t + B_0' \sin q t\}$$

and these are the usual equations of the condenser discharge through an inductive circuit, which here appear as a special case of a special case of the general circuit equations.

If q equals zero, the functions D in equations (45) and (46) become constant, and these equations assume the form:

$$i = \varepsilon^{-wt} \Sigma \{[C_1 \varepsilon^{+f(t-\lambda)} + C_3 \varepsilon^{-f(t-\lambda)}] - [C_2 \varepsilon^{+f(t+\lambda)} + C_4 \varepsilon^{-f(t+\lambda)}]\}$$

$$e = \sqrt{\frac{L}{C}}\, \varepsilon^{-wt} \Sigma \{[C_1 \varepsilon^{+f(t-\lambda)} + C_3 \varepsilon^{-f(t-\lambda)}] + [C_2 \varepsilon^{+f(t+\lambda)} + C_4 \varepsilon^{-f(t+\lambda)}]\}$$

This gives expressions of current and voltage, which are not oscillatory any more, but exponential, representing a gradual change of i and e as functions of time and distance, corresponding to the gradual or logarithmic condenser discharge. For $\lambda = 0$, these equations change to the equations of the logarithmic condenser discharge.

These equations are only approximate however, since in them the quantities f, w, h, have been neglected compared with q, assuming the latter as very large, while now it is assumed as zero.

It thus follows:

If the constant h in equations (29) and (30) differs from zero, the oscillation (using the term *oscillation* here in the most general sense, that is, including also *alternation*, as an oscillation of zero attenuation) travels along the circuit; but it becomes stationary, as standing wave, for $h = 0$. That is:

The distance attenuation constant h may also be called the *propagation* constant of the wave.

$h = 0$ thus represents a wave which does not propagate or move along the circuit, but stands still, that is, a stationary or standing wave.

III. STANDING WAVES.

10. If the propagation constant of the wave vanishes:

$$h = 0$$

the wave becomes a stationary or standing wave, and the equations of the standing wave so are derived from the general equations, by substituting thereon: $h = 0$.

This gives:

$$R_2{}^2 = \sqrt{(k^2 - L\,C\,m^2)^2}$$

hence, if:

$$k^2 > L\,C\,m^2\colon\ R_2{}^2 = k^2 - L\,C\,m^2,$$

and, if:

$$k^2 < L\,C\,m^2\colon\ R_2{}^2 = L\,C\,m^2 - k^2$$

Two different cases exist, depending upon the relative values of k^2 and $L\,C\,m^2$, and in addition thereto the intermediary or critical case, in which $k^2 = L\,C\,m^2$.

These three cases require separate consideration.

$$L C m^2 = \left\{ L C \tfrac{1}{2} \left(\frac{r}{L} - \frac{g}{C} \right) \right\}^2$$

is a circuit constant, while k is the wave length constant, that is, the higher k, the shorter is the wave length.

A. *Short Waves*:

$$k^2 > L C m^2$$

hence:

$$R_2^2 = k^2 - L C m^2$$

and,

$$f = 0$$

and approximately,

$$q = \frac{k}{\sqrt{L C}}$$

Substituting in equations (29), (30), the two waves i', e', and i'', e'', coincide, and all the exponential terms reduce to ε^{-wt}, and rearranged, give,

$$i = \varepsilon^{-wt} \{[B_1 \cos (qt - ku) + B_1' \sin (qt - ku)] - [B_2 \cos (qt + ku) + B_2' \sin (qt + ku)]\} \qquad (52)$$

$$e = \sqrt{\frac{L}{C}} \varepsilon^{-wt} \{[B_1 \cos (qt - ku) + B_1' \sin (qt - ku)] + [B_2 \cos (qt + ku) + B_2' \sin (qt + ku)]\} \qquad (53)$$

These equations represent a *stationary electrical oscillation* or standing wave in the circuit.

B. *Long Waves*:

$$k^2 < L C m^2$$

hence:

$$R_2^2 = L C m^2 - k^2$$

and:

$$f = \sqrt{m^2 - \frac{k^2}{LC}}$$

$$q = 0$$

or approximately, for very small values of k:

$$f = m = \frac{1}{2}\left(\frac{r}{L} - \frac{g}{C}\right)$$

Substituting now into (29) and (30), the two waves i', e', and i'', e'', remain separate, having different exponential terms, $\varepsilon^{-(w-f)t}$ and $\varepsilon^{-(w+f)t}$, but in each of the two waves, the main wave and the reflected wave coincide, due to the vanishing of q.

$$i = \varepsilon^{-wt}\left\{(B_1\,\varepsilon^{+ft} + B_2\,\varepsilon^{-ft})\cos ku - (B_1'\,\varepsilon^{+ft} + B_2'\,\varepsilon^{-ft})\sin ku\right\} \tag{54}$$

$$e = \sqrt{\frac{L}{C}}\,\varepsilon^{-wt}\left\{[(m+f)\,B_1'\,\varepsilon^{+ft} + (m-f)\,B_2'\,\varepsilon^{-ft}]\cos ku + [(m+f)\,B_1\,\varepsilon^{+ft} + (m-f)\,B_2\,\varepsilon^{-ft}]\sin ku\right\}$$

$$= \sqrt{\frac{L}{C}}\,\varepsilon^{-wt}\left\{m\,[(B_1'\,\varepsilon^{+ft} + B_2'\,\varepsilon^{-ft})\cos ku + (B_1\varepsilon^{+ft} + B_2\varepsilon^{-ft})\sin ku] + f\,[(B_1'\varepsilon^{+ft} - B_2'\varepsilon^{-ft})\cos ku + (B_1\varepsilon^{+ft} - B_2\varepsilon^{-ft})\sin ku]\right\}$$

These equations represent a *gradual or exponential circuit discharge.* The distribution is a trigonometric function of the distance, that is, a wave distribution, but dies out gradually in time, or without oscillation.

C. *Critical Case*:

$$k^2 = L\,C\,m^2$$

This gives:

$$i = \varepsilon^{-wt}\left\{B\cos ku - B'\sin ku\right\}$$

$$e = \sqrt{\frac{L}{C}}\,\varepsilon^{-wt}\left\{B'\cos ku + B\sin ku\right\}$$

In the critical case, the wave is distributed as trigonometric function of the distance, but dies out as simple exponential function of the time.

11. An electrical standing wave can have two different forms: it can be either oscillatory in time, or exponential in time, that is, gradually changing. It is interesting to investigate the conditions under which these two different cases occur.

The transition from gradual to oscillatory, takes place at:

$$k_0^2 = m^2 L C$$

for larger values of k, the phenomenon is oscillatory; for smaller, exponential or gradual:

As k is the wave length constant, the wave length, at which the phenomenon ceases to be oscillatory in time, and becomes a gradual dying out, is given by:

$$U_0 = \frac{2\pi}{k_0}$$

$$= \frac{2\pi}{m\sqrt{L C}}$$

In an undamped wave, that is, in a circuit of zero r and zero g, in which no energy losses occur, the velocity of propagation is:

$$v = \frac{q}{k} = \frac{1}{\sqrt{L C}}$$

and is the velocity of light:

$$v_0 = 3 \times 10^{10}$$

if the medium has unit permeability and unit inductivity.

In an undamped circuit, this wave length U_0 would correspond to the frequency:

$$q_0 = \frac{k_0}{\sqrt{L C}} = m$$

hence:

$$N_0 = \frac{q_0}{2\pi} = \frac{m}{2\pi}$$

The frequency, at the wave length U_0, is however, zero, as at this wave length the phenomenon ceases to be oscillatory. That is:

Due to the energy losses in the circuit, by the effective resistance r and effective conductance g, the frequency N of the wave is reduced below the value corresponding to the wave length U, the more, the greater the wave length, until at the wave length U_0 the frequency becomes zero, and the phenomenon thereby non-oscillatory. This means, with increasing wave length, the velocity of propagation of the phenomenon decreases, and becomes zero at wave length U_0.

$$\text{If } m^2 L C = 0, \; k_0 = 0, \text{ and } \; U_0 = \infty,$$

that is, the standing wave is always oscillatory.

$$\text{If } m^2 L C = \infty, \; k_0 = \infty, \text{ and } U_0 = 0,$$

that is, the standing wave is always non-oscillatory, or gradually dying out.

In the former case:

$$m^2 L C = 0, \text{ or oscillatory phenomenon,}$$

it is, substituting for m^2 and expanding:

$$\frac{r}{g} = \frac{L}{C}$$

or:

$$r C - g L = 0$$

In the latter case:

$m^2 L C = \infty$, or non-oscillatory or exponential standing wave, it is either:

$$L = 0, \; \text{or } C = 0.$$

That is:

The standing wave in a circuit is always oscillatory, regardless of its wave length, if

$$\frac{r}{g} = \frac{L}{C},$$

that is, the ratio of the energy coefficients equals the ratio of the reactive coefficients of the circuit.

The standing wave can never be oscillatory, but is always exponential, or gradually dying out, if either the inductance L, or the capacity C, vanish, that is, the circuit contains no capacity or contains no inductance. In all other cases, the standing wave is oscillatory for waves longer than the critical value $U_0 = \frac{2\pi}{k_0}$, where

$$k_0^2 = m^2 L C = \tfrac{1}{4} \left\{ r \sqrt{\frac{C}{L}} - g \sqrt{\frac{L}{C}} \right\}^2 \qquad (56)$$

and is exponential or gradual, for standing waves shorter than the critical wave length U_0. Or, for $k > k_0$, the standing wave is exponential; for $k < k_0$, it is oscillatory.

The term $k_0 = m \sqrt{L C}$ takes a similar part in the theory of standing waves as the term: $r_0^2 - 4 L_0 C_0$ in the condenser discharge through an inductive circuit, that is, it separates the exponential or gradual, from trigonometric or oscillatory conditions.

The difference is, that the condenser discharge through an inductive circuit is gradual, or oscillatory, depending on the circuit constants, while in a general circuit, with the same circuit constants, in general gradual as well as oscillatory standing waves exist, the former at greater wave length, or

$$m \sqrt{L C} > k,$$

the latter for shorter wave length, or

$$m \sqrt{L C} < k,$$

An idea of the quantity k_0, and so the wave length U_0, at which the frequency of the standing wave becomes zero, or the wave non-oscillatory, and of the frequency N_0, which in an undamped circuit will correspond to this critical wave length N_0, can best be derived by considering some representative numerical instance.

1. *High Power High Potential Overhead Transmission Line.*

12. Assuming power to be transmitted 120 miles, at 40,000 volts between line and ground, by a three-phase system with grounded neutral, over a line consisting of copper conductors, wire No. 00 B. & S. gauge with 5 feet between conductors.

Choosing as unit length the mile, it is, approximately,

$$r = .41 \text{ ohms}$$
$$L = 1.95 \times 10^{-3}\, h$$
$$g = .25 \times 10^{-6} \text{ mho}$$
$$C = .0162 \times 10^{-6}\, f.$$

Herefrom then follows:

$$w = 113$$
$$m = 97$$
$$\sigma = \sqrt{L C} = 5.62 \times 10^{-6}$$
$$k_0 = m L C = 545 \times 10^{-6}$$

hence, the critical wave length:

$$U_0 = \frac{2\pi}{k_0} = 11{,}500 \text{ miles}$$

and, in an undamped circuit, this wave length would correspond to the frequency of oscillation:

$$N_0 = \frac{m}{2\pi} = 15.7 \text{ cycles per second.}$$

Since the shortest wave at which the phenomenon ceases to be oscillatory, is 11,500 miles in length, and the longest wave, which can originate in the circuit, is 4 times the length of the circuit, or 480 miles, it follows that whatever waves may originate in this circuit, are by necessity oscillatory, and non-oscillatory currents or voltages can exist in this circuit only when impressed upon it by some outside source, and then are of such great wave length, that the circuit is only an insignificant fraction of the wave, and great differences of voltage and current of non-oscillatory nature cannot exist.

Since the difference in length, between the shortest non-oscillatory wave, and the longest wave which can originate in the circuit, is so very great, it follows, that in high potential long distance transmission circuits, all phenomena which may result in considerable potential differences and differences of current throughout the circuit, are oscillatory in nature.

With a length of circuit of 120 miles, the longest standing wave, which can originate in the circuit, has the wave length:

$$U = 480 \text{ miles.}$$

and herefrom follows:

$$k = \frac{2\pi}{U} = .0134$$

$$q = \frac{k}{\sqrt{L\,C}} = 2380$$

$$N = \frac{q}{2\pi} = 380 \text{ cycles.}$$

Hence, even for the longest standing wave, which may originate in this transmission line, and still more so for shorter waves, the overtones of the fundamental wave, the approximations in paragraph 7 are justified, and it thus is:

General Equations of Standing Waves in Long Distance Power Transmission Lines:

$$i = \Sigma\, \epsilon^{-wt} \{[B_1 \cos (qt - ku) + B_1' \sin (qt - ku)] - [B_2 \cos (qt + ku) + B_2' \sin (qt + ku)]\} \qquad (57)$$

$$e = + \sqrt{\frac{L}{C}}\, \Sigma \epsilon^{-wt} \{[B_1 \cos (qt - ku) + B_1' \sin (qt - ku)] + [B_2 \cos (qt + ku) + B_2' \sin (qt + ku)]\} \qquad (58)$$

or:

$$e = \Sigma \epsilon^{-wt} \{[A_1 \cos (qt + ku) + A_1' \sin (qt + ku)] + [A_2 \cos (qt - ku) + A_2' \sin (qt - ku)]\} \qquad (59)$$

$$i = \sqrt{\frac{C}{L}}\, \Sigma \epsilon^{-wt} \{[A_1 \cos (qt + ku) + A_1' \sin (qt + ku)] - [A_2 \cos (qt - ku) + A_2' \sin (qt - ku)]\} \qquad (60)$$

where:

$$A_1 = -\sqrt{\frac{L}{C}}\, B_2$$

$$A_1' = -\sqrt{\frac{L}{C}}\, B_2'$$

etc.

2. *High Potential Underground Power Cable.*

13. Assuming, per mile of single conductor:

$r = .41$ ohms.

$L = .4 \times 10^{-3}\, h$.

$g = 1 \times 10^{-6}$ mho, corresponding to a power factor of the cable charging current, at 25 cycles, of 1 per cent.

$C = .6 \times 10^{-6}\, f$.

Herefrom then follows:

$$w = 513$$

$$m = 512$$

$$\sigma = \sqrt{LC} = 15.5 \times 10^{-6}$$

$$k_0 = m\sqrt{LC} = 7.95 \times 10^{-3}$$

and, critical wave length:

$$U_0 = 790 \text{ miles,}$$

and, frequency of an undamped oscillation, corresponding to U_0:

$$N_0 = 81.5 \text{ cycles.}$$

As seen, in an underground high potential cable, the critical wave length is very much shorter than in the overhead long distance transmission line. At the same time, however, the length of an underground cable circuit is very much shorter than that of a long distance transmission line, so that the critical wave length still is very large compared with the greatest wave length of an oscillation originating in the cable; about 10 times as great.

That is, the discussion of the possible phenomena in any overhead line applies also to the underground high potential cable circuit.

3. *Submarine Telegraph Cable.*

Choosing the values:

Length of cable, 4000 miles.

Constants per mile of conductor:

$$r = 3 \text{ ohms}$$

$$L = 1 \times 10^{-3}\, h$$

$$g = 1 \times 10^{-6} \text{ mho}$$

$$C = .1 \times 10^{-6}\, f$$

hence:

$$w = 1500$$

$$m = 1500$$

$$\sigma = L\,C = 10 \times 10^{-6}$$

$$k_0 = m\sqrt{L\,C} = 15 \times 10^{-3}$$

and:

$$U_0 = 418 \text{ miles}$$

thus:

$$N_0 = 477 \text{ cycles.}$$

That is, in a submarine cable, the critical wave length U_0 is relatively short, so that in long submarine cables, standing waves may appear, which are not oscillatory in time, but die out gradually. In such cables, due to their relative high resistance, the damping effect is very great, $w = 1500$, and standing waves rapidly die out.

In the investigation of the submarine cable, the complete equations must therefore be used, and q cannot always be assumed as large compared with m and w, except when dealing with local oscillations.

4. *Long Distance Overhead Telephone Circuit.*

14. Considering a telephone circuit of 1000 miles length, metallic return, consisting of two wires No. 4 B. & S. gauge, 24 in. distant from each other.

Per mile of conductor:

$$r = 1.31 \text{ ohms}$$

$$L = 1.84 \times 10^{-3}\, h$$

$$C = .0172 \times 10^{-6}\, f$$

as conductance g we may assume:

(a) $g = 0$, that is, very perfect insulation, as in dry weather.

(b) $q = 2.5 \times 10^{-6}$, that is, slightly leaky lines.

(c) $g = 12 \times 10^{-6}$, that is, poor insulation, or a leaky line.

(d) $g = 40 \times 10^{-6}$, that is, extremely poor insulation, as during heavy rain.

The condition may also be investigated where the line is loaded with inductance coils, spaced so close together, that in their effect we can consider this additional inductance as uniformly distributed. Let the total inductance, per unit length, be increased by the loading coils to:

$$L_1 = 9 \times 10^{-3}\, h$$

or about 5 times the normal value.

Denoting then the constants of the loaded line by the index 1, it is:

			(a)	(b)	(c)	(d)
w	=	=	356	429	706	1518
w_1	=	=	73	146	423	1236
m	=	=	356	283	6	-806
m_1	=	=	73	0	-277	-1090
σ	$=\sqrt{LC}$	$= 5.63 \times 10^{-6}$				
σ_1	$=\sqrt{L_1 C}$	$= 12.45 \times 10^{-6}$				
k_0	$= m\sqrt{LC}$	=	2×10^{-3}	1.6×10^{-3}	33.7×10^{-6}	4.56×10^{-3}
k_{01}	$= m_1\sqrt{L_1 C}$	=	91×10^{-6}	0	3.45×10^{-3}	13.5×10^{-3}
U_0	=	=	3140	3920	187,000	1380
U_{01}	=	=	69,000	∞	1820	464
N_0	=	=	55.6	45	.96	128
N_{01}	=	=	11.6	0	44	173

Hence, in a long distance telephone line, distributed leakage up to a certain amount, increases the critical wave length, and so makes even the long wave oscillatory. Beyond this amount, leakage again decreases the wave length. Distributed inductance, as by loading the line, increases the critical wave length, if the leakage is small, but in a badly leaky line, it decreases the critical wave length, and the amount of leakage, up to which an increase of the critical wave length occurs, is less, in a loaded line, that is, in a line of higher inductance.

In other words, a moderate amount of distributed leakage improves a long distance telephone line, an excessive amount of leakage spoils it. An increase of inductance, by loading the line, improves the line, if the leakage is small, but spoils the line, if the leakage is considerable. The amount of leakage up to which improvement in the telephone line occurs, is less in a loaded than in an unloaded line, that is, a loaded telephone line requires a far better insulation than an unloaded line.

IV. TRAVELING WAVES.

15. As seen, especially in electric power circuits, overhead or underground, the longest existing standing wave has a wave length which is so small compared with the critical wave length —where the frequency becomes zero—that the effect of the damping constant on frequency and wave length is negligible. The same obviously applies also to traveling waves, generally to a greater extent still, since traveling waves commonly are of wave lengths, which are only a small part of the length of the circuit. Usually therefore in the discussion of traveling waves, the effect of the damping constants on the frequency constant q and the wave length constant k can be neglected, that is, frequency and wave length assumed as independent of the energy loss in the circuit, and the equations (45) and (46) applied in dealing with the traveling wave.

In these equations, the distance traveled by the wave per second, is used as unit length, by the substitution:

$$\lambda = \sigma u$$

where:

$$\sigma = \sqrt{L C}$$

as this brings t and λ into direct comparison, and eliminates h and k from the equations, by the equation (43).

This gives, under the limiting conditions discussed before, the

General Equations of the Traveling Wave:

$$\begin{aligned} i = \varepsilon^{-wt} \{ & \varepsilon^{+f(t-\lambda)} [B_1 \cos q (t-\lambda) + B_1' \sin q (t-\lambda)] - \varepsilon^{+f(t+\lambda)} [B_2 \cos \\ & q (t+\lambda) + B_2' \sin q (t+\lambda)] + \varepsilon^{-f(t-\lambda)} [B_3 \cos q (t-\lambda) + B_3' \\ & \sin q (t-\lambda)] - \varepsilon^{-f(t+\lambda)} [B_4 \cos q (t+\lambda) + B_4' \sin q (t+\lambda)] \} \end{aligned} \tag{61}$$

$$e = \sqrt{\frac{L}{C}}\,\epsilon^{-wt}\left\{\epsilon^{+f(t-\lambda)}\left[B_1 \cos q\,(t-\lambda) + B_1' \sin q\,(t-\lambda)\right] + \epsilon^{+f(t+\lambda)}\left[B_2 \cos q(t+\lambda) + B_2' \sin q(t+\lambda)\right] + \epsilon^{-f(t-\lambda)}\left[B_3 \cos q(t-\lambda) + B_3' \sin q\,(t-\lambda)\right] + \epsilon^{-f(t+\lambda)}\left[B_4 \cos q\,(t+\lambda) + B_4' \sin q\,(t+\lambda)\right]\right\} \qquad (62)$$

or:

$$e = \epsilon^{-wt}\left\{\epsilon^{+f(t-\lambda)}\left[A_1 \cos q\,(t-\lambda) + A_1' \sin q\,(t-\lambda)\right] + \epsilon^{+f(t+\lambda)}\left[A_2 \cos q\,(t+\lambda) + A_2' \sin q(t+\lambda)\right] + \epsilon^{-f(t-\lambda)}\left[A_3 \cos q\,(t-\lambda) + A_3' \sin q\,(t-\lambda)\right] + \epsilon^{-f(t+\lambda)}\left[A_4 \cos q\,(t+\lambda) + A_4' \sin q\,(t+\lambda)\right]\right\} \qquad (63)$$

$$i = \sqrt{\frac{C}{L}}\,\epsilon^{-wt}\left\{\epsilon^{+f(t-\lambda)}\left[A_1 \cos q\,(t-\lambda) + A_1' \sin q\,(t-\lambda)\right] - \epsilon^{+f(t+\lambda)}\left[A_2 \cos q\,(t+\lambda) + A_2' \sin q\,(t+\lambda)\right] + \epsilon^{-f(t-\lambda)}\left[A_3 \cos q\,(t-\lambda) + A_3' \sin q\,(t-\lambda)\right] - \epsilon^{-f(t-\lambda)}\left[A_4 \cos q\,(t+\lambda) + A_4' \sin q\,(t+\lambda)\right]\right\} \qquad (64)$$

where:

$$w = \tfrac{1}{2}\left(\frac{r}{L} + \frac{g}{C}\right) \qquad (65)$$

In these equations the values A, B, are integration constants, which are determined by the terminal conditions of the problem.

The terms with $(t-\lambda)$ may be considered as the main wave, the terms with $(t+\lambda)$ as the reflected wave, or inversely, depending on the direction of propagation of the wave.

16. As the traveling wave consists of a main wave, with variable $(t-\lambda)$, and a reflected wave of the same character, but moving in opposite direction, thus with the variable $(t+\lambda)$, these waves may be studied separately, and afterwards the effect of their combination investigated.

Thus, considering at first one of the waves only, that with the variable $(t-\lambda)$, it is, from equations (63) to (64):

$$e = \epsilon^{-wt}\left\{\epsilon^{+f(t-\lambda)}\left[A_1 \cos q\,(t-\lambda) + A_1' \sin q\,(t-\lambda)\right] + \epsilon^{-f(t-\lambda)}\left[A_3 \cos q\,(t-\lambda) + A_3' \sin q\,(t-\lambda)\right]\right\} \qquad (66)$$

$$= \epsilon^{-wt}\left\{\left(A_1\,\epsilon^{+f(t-\lambda)} + A_3\,\epsilon^{-f(t-\lambda)}\right) \cos q\,(t-\lambda) + \left(A_1'\,\epsilon^{+f(t-\lambda)} + A_3'\,\epsilon^{-f(t-\lambda)}\right) \sin q\,(t-\lambda)\right\}$$

and:

$$i = \sqrt{\frac{C}{L}}\, e$$

That is, in a single traveling wave, current and voltage are in phase with each other, and proportional to each other, with an *effective impedance*:

$$z = \frac{e}{i} = \sqrt{\frac{L}{C}}$$

This proportionality between e and i, and coincidence of phase, obviously does not exist any more in the combination of main waves and reflected waves, since in reflection, the current reverses with the reversal of the direction of propagation, while the voltage remains in the same direction.

In equation (66), the time t appears only in the term $(t-\lambda)$, except in the factor ε^{-wt}, while the distance λ appears only in the term $(t-\lambda)$. Substituting therefore:

$$\vartheta = t - \lambda$$

hence:

$$t = \vartheta + \lambda$$

that is, counting the time differently at any point λ, and counting it at every point of the circuit from the same point in the phase of the wave, from which the time t is counted at the starting point of the wave, $\lambda = 0$, or, in other words, shifting the starting point of the counting of time, with the distance λ, it is, substituted in (66):

$$\left.\begin{aligned} e &= \varepsilon^{-wt} \left\{ \varepsilon^{+f\vartheta} (A_1 \cos q\vartheta + A_1' \sin q\vartheta) + \varepsilon^{-f\vartheta} (A_3 \cos q\vartheta \right. \\ &\qquad \left. + A_3' \sin q\vartheta) \right\} \\ &= \varepsilon^{-w\lambda-}\varepsilon^{w\vartheta} \left\{ \varepsilon^{+f\vartheta} (A_1 \cos q\vartheta + A_1' \sin q\vartheta) + \varepsilon^{-f\vartheta} (A_3 \cos q \right. \\ &\qquad \left. \vartheta + A_3 \sin q\vartheta) \right\} \\ &= \varepsilon^{-w\lambda}\, \varepsilon^{-w\vartheta} \left\{ (A_1 \varepsilon^{+f\vartheta} + A_3 \varepsilon^{-f\vartheta}) \cos q\vartheta + (A_1' \varepsilon^{+f\vartheta} + A_3' \right. \\ &\qquad \left. \varepsilon^{-f\vartheta}) \sin q\vartheta) \right\} \end{aligned}\right\} \quad (67)$$

The latter form of the equation is best suited to represent the variation of the wave, at a fixed point λ in space, as function of the local time ϑ.

The wave is the product of a term: ϵ^{-w} which decreases with increasing distance λ, and a term:

$$
\begin{aligned}
e_0 &= \epsilon^{-w\vartheta}\{\epsilon^{+f\vartheta}(A_1 \cos q\vartheta + A_1' \sin q\vartheta) + \epsilon^{-f\vartheta}(A_3 \cos q\vartheta + A_3' \sin q\vartheta)\} \\
&= \epsilon^{-w\vartheta}\{(A_1\epsilon^{+f\vartheta} + A_3\epsilon^{-f\vartheta}) \cos q\vartheta + (A_1'\epsilon^{+f\vartheta} + A_3'\epsilon^{-f\vartheta}) \sin q\vartheta)\}
\end{aligned}
\qquad (68)
$$

which latter term is independent of the distance, but merely a function of the time ϑ, when counting the time at any point of the line from the moment of the passage of the same phase of the wave.

Since the coefficient in the exponent of the distance decrement $\epsilon^{-w\lambda}$, contains only the circuit constants:

$$w = \frac{1}{2}\left(\frac{r}{L} + \frac{g}{C}\right)$$

but does not contain f and q, or the other integration constants.

It follows herefrom:

The attenuation constant of a traveling wave, and therefore the distance decrement of the wave depends upon the circuit constants r, L, g, C, only, but does not depend upon the wave length, frequency, voltage or current; hence all traveling waves in the same circuit die out at the same rate, regardless of their frequency and of their wave shape, or in other words, a complex traveling wave retains its wave shape, when traversing a circuit, and merely decreases in amplitude by the distance decrement $\epsilon^{-w\lambda}$.

The wave attenuation is a constant of the circuit.

This obviously applies only for waves of constant velocity, that is, such waves in which q is large compared with f, w, and m, and does not strictly apply to extremely long waves, as discussed in 13.

17. By changing the line constants, as by inserting inductance in such a manner as to give the effect of uniform distribution (loading the line), the attenuation of the wave can be reduced, that is, the wave caused to travel a greater distance u with the same decrease of amplitude.

As function of the inductance L, the attenuation constant is a minimum for:

$$\frac{d\,w_0}{d\,L} = 0$$

hence:

$$r\,C - g\,L = 0$$

or:

$$\frac{L}{C} = \frac{r}{g}$$

and, if the conductance:

$$g = 0$$

it is:

$$L = \infty$$

Hence, in a perfectly insulated circuit, or circuit having no energy losses depending on the voltage, the attenuation decreases with increase of the inductance, that is, by "loading the line", and the more inductance is inserted, the better the telephonic transmission is.

In a leaky telephone line, increase of inductance decreases the attenuation, and so improves the telephonic transmission, up to the value of inductance,

$$L = \frac{r\,C}{g}$$

and beyond this value, inductance is harmful, by again increasing the attenuation.

For instance, if in a long distance telephone circuit per mile:

$$r = 1.31 \text{ ohms}$$
$$L = 1.84 \times 10^{-3}\ h$$
$$g = 1.0 \times 10^{-6} \text{ mho}$$
$$C = 0.0172 \times 10^{-6}\ f$$

the attenuation of a traveling wave or impulse is:

$$w_0 = 0.00217$$

hence, for a distance or length of line of $l = 2000$ miles:

$$\varepsilon^{-w_0 l} = \varepsilon^{-4.34}$$
$$= 0.0129$$

that is, the wave is reduced to 1.29 per cent. of its original value.

The best value of inductance is, by

$$L = \frac{r}{g} C = 0.0225\, h$$

and in this case, the attenuation constant becomes:

$$w_0 = 0.00114$$

and thus:

$$\varepsilon^{-w_0 l} = \varepsilon^{-2.24}$$
$$= 0.1055$$

or 10.55 per cent of the original value of the wave.

In this telephone circuit, by adding per mile an additional inductance of:

$$22.5 - 1.84 = 20.7 \text{ mh.}$$

the intensity of the arriving wave is increased from 1.29 per cent. to 10.55 per cent. or more than 8 times.

If however, in wet weather, the leakage increases to the value:

$$g = 5 \times 10^{-6}$$

in the unloaded line, it is:

$$w_0 = 0.00282$$
$$\varepsilon^{-w_0 l} = 0.0035$$

while in the loaded line, it is:

$$w_0 = 0.00341$$
$$\varepsilon^{-w_0 l} = 0.0011$$

and while with the unloaded line, the arriving wave is still 0.35 per cent. of the outgoing wave, in the loaded line, it is only 0.11 per cent.; that is, in this case, loading the line with inductance has badly spoiled telephonic communication and increased the decay of the wave more than three-fold. A loaded telephone line is much more sensitive to changes of leakage g, that is, to meteorological conditions.

18. The equation of the traveling wave (67):

$$e = \varepsilon^{-w\lambda} \varepsilon^{-w\vartheta} \{\varepsilon^{+f\vartheta} (A_1 \cos q\vartheta + A_1 \sin q\vartheta) + \varepsilon^{-f\vartheta} (A_3 \cos q\vartheta + A_3' \sin q\vartheta)\} \qquad (67)$$

can be reduced to the form:

$$e = \varepsilon^{-w\lambda} \{E_1 \varepsilon^{-w\vartheta_1} (\varepsilon^{+f\vartheta_1} - \varepsilon^{-f\vartheta_1}) \sin q\vartheta_1 + E_2 \varepsilon^{-w\vartheta_2} (\varepsilon^{+f\vartheta_2} - \varepsilon^{-f\vartheta_2}) \cos q\vartheta_2\} \qquad (69)$$

where:

$$\vartheta_1 = \vartheta + \gamma_1 = t - \lambda - \gamma_1$$

$$\vartheta_2 = \vartheta + \gamma_2 = t - \lambda - \gamma_2$$

Any traveling wave can be resolved into, and considered as consisting of, a combination of 2 waves: the

Traveling Sine Wave:

$$e_1 = E_1 \varepsilon^{-w\lambda} \varepsilon^{-w\vartheta} (\varepsilon^{+f\vartheta_1} - \varepsilon^{-f\vartheta_1}) \sin q\vartheta_1 \qquad (70)$$

Traveling Cosine Wave:

$$e_2 = E_2 \varepsilon^{-w\lambda} \varepsilon^{-w\vartheta_2} (\varepsilon^{+f\vartheta_2} - \varepsilon^{-f\vartheta_2}) \cos q\vartheta_2 \qquad (71)$$

Since q is a large quantity compared with w and f, the two component traveling waves, (70) and (71), differ appreciably from each other in appearance only for very small values of ϑ, that is, near $\vartheta_1 = 0$ and $\vartheta_2 = 0$. The traveling sine wave rises in the first half cycle very slightly, while the traveling cosine wave rises rapidly, *i.e.*, the tangent of the angle which the wave makes with the horizontal, or $\frac{de}{dt}$, equals 0 with the sine wave, and has a definite value with the cosine wave.

All traveling waves in an electric circuit can be resolved into constituent elements, traveling sine waves and traveling cosine waves, and the general traveling wave consists of four component waves, a sine wave, its reflected wave, a cosine wave, and its reflected wave.

The elements of the traveling wave, the traveling sine wave e_1, and the traveling cosine wave e_2, contain 4 constants:

The intensity constant: E

The attenuation constant: w respectively w_0

The frequency constant: q

And the constant: f

The wave starts from zero, builds up to a maximum, and then gradually dies out, to zero at infinite time.

The absolute term of the wave, that is, the term which represents the values between which the wave oscillates, is:

$$e_0 = E\,\varepsilon^{-w\lambda}\,\varepsilon^{-w\vartheta}\left(\varepsilon^{+f\vartheta} - \varepsilon^{-f\vartheta}\right) \tag{72}$$

This term e_0 may be called the *amplitude* of the wave. The amplitude e_0 is a maximum for the value of ϑ, given by:

$$\frac{d\,e_0}{d\,\vartheta} = 0$$

$$\vartheta_0 = \frac{1}{2f}\,lg\,\frac{w+f}{w-f} \tag{73}$$

and, substituting this value into the equation of the absolute term of the wave, (72), gives:

$$e_m = E\,\varepsilon^{-w\lambda}\,\frac{2f}{\sqrt{w^2 - f^2}}\left(\frac{w+f}{w-f}\right)^{-\frac{w}{2f}}$$

The rate of building up of the wave, or the steepness of the wave front, is given by:

$$G_0 = \left|\frac{d\,e_0}{d\,\vartheta}\right|_{\vartheta = 0}$$

$$= 2\,f\,E\,\varepsilon^{-w\lambda}$$

It is a maximum, that is, ϑ_0 a minimum, for the value of f, in equation (73), given by:

$$\frac{d\,\vartheta_0}{d\,f} = 0$$

or:

$$f = 0$$

or the standing wave, which rises infinitely fast, that is, appears instantly.

The smaller therefore f is, the more rapidly is the rise of the traveling wave, and f may be called the *acceleration constant* of the traveling wave.

ϑ is the time counted from the beginning of the wave.

Since:

$$\vartheta = t - \lambda - \gamma$$

if we change the zero point of the distance, that is, count the distance λ from that point of the line, at which the wave starts at time $t = 0$, or in other words, count time t and distance λ from the origin of the wave, it is:

$$\vartheta = t - \gamma$$

and the traveling wave so may be represented by:

The amplitude:

$$e_0 = E\,\varepsilon^{-wt}\,(\varepsilon^{+f\vartheta} - \varepsilon^{-f\vartheta})$$

The sine wave:

$$e_1 = E\,\varepsilon^{-wt}\,(\varepsilon^{+f\vartheta} - \varepsilon^{-f\vartheta}) \sin q\,\vartheta = e_0 \sin q\,\vartheta \qquad (74)$$

The cosine wave:

$$e_2 = E\,\varepsilon^{-wt}\,(\varepsilon^{+f\vartheta} - \varepsilon^{-f\vartheta}) \cos q\,\vartheta = e_0 \cos q\,\vartheta$$

and $\vartheta = t - \lambda$ can be considered as the distance, counting backwards from the wave front, or the distance counted with the point λ, which the wave has just reached, as zero point, and in opposite direction to λ, or as the time, counting from the moment of the arrival of the wave front.

Equation (74) represents the distribution of the wave along the line, at the moment t, or the variation of the wave with the time, at a point λ.

As seen, the wave maintains its shape, but progresses along the line, and at the same time dies out, by the time decrement ε^{-wt}.

19. As an instance may be considered a traveling wave of the constants:

$$w = 115$$
$$f = 45$$
$$q = 2620$$
$$E = 100$$

hence:

$$e_0 = 100\,\varepsilon^{-115t}\,(\varepsilon^{+45\vartheta} - \varepsilon^{-45\vartheta})$$

$$= 100\,\varepsilon^{-115\lambda}\,(\varepsilon^{-70\vartheta} - \varepsilon^{-160\vartheta})$$

where:

$$\vartheta = t - \lambda$$

In Fig. 2 is shown the amplitude e_0, as function of the distance λ, for the different values of time:

$$t = 2,\ 4,\ 8,\ 12,\ 16,\ 20,\ 24 \text{ and } 32 \times 10^{-3}$$

with the maximum amplitude e_m, in dotted line, as envelope of the curves of e_0.

As seen, the amplitude of the wave gradually rises, and at the same time spreads over the line, reaching the maximum at the starting point $\lambda = 0$ at the time $t_0 = 9.2 \times 10^{-3}$ sec., and then decreases again while continuing to spread over the line, until it gradually dies out.

It is interesting to note that the distribution curves of the amplitude are nearly straight lines, but also, that even in the longest power transmission line the wave has reached the end of the line, and reflection occurs, before the maximum of the wave is reached: the unit of length λ is the distance traveled by the wave per second, or 188,000 miles, and during the rise of the wave, at the origin, from its start to the maximum, or 9.2×10^{-3} sec., the wave has traveled 1760 miles, thus the reflected wave would have returned to the origin before the maximum of the wave is reached, if the circuit is shorter than 880 miles.

Fig. 3 shows the passage of the traveling wave: $e_1 = e_0 \sin q\,\vartheta$, across a point λ of the line, with the local time ϑ as abscissas, and the instantaneous values of e_1 as ordinates. The values are given for $\lambda = 0$, where $\vartheta = t$; for any other point of the line, λ, the wave shape is the same, but all the ordinates reduced by the factor $\varepsilon^{-115\lambda}$, in the proportion as shown in the dotted curve in Fig. 2.

Fig. 4 shows the beginning of the passage of the traveling wave across a point $\lambda = 0$ of the line, that is, the starting of a

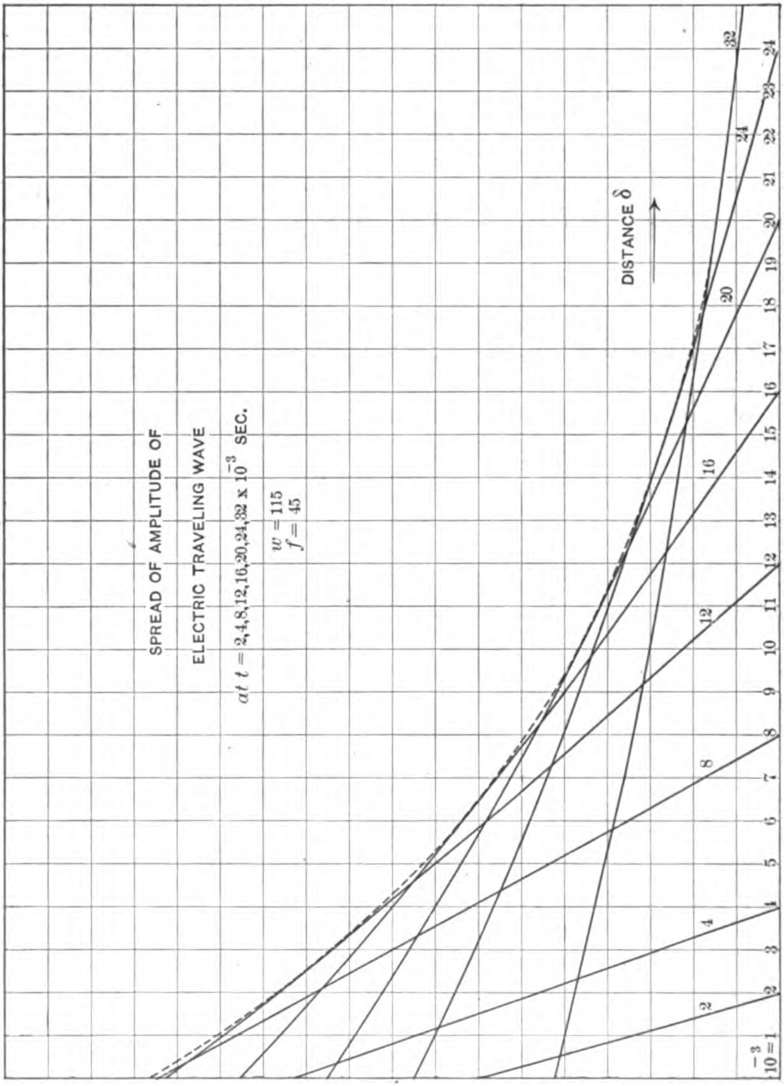

SPREAD OF AMPLITUDE OF
ELECTRIC TRAVELING WAVE
at $t = 2,4,8,12,16,20,24,32 \times 10^{-3}$ SEC.
$w = 115$
$f = 45$
DISTANCE δ
2
4
8
12
16
20
24
32
$10^{-3} = 1$
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

FIG. 2

wave, or its first one and one-half cycles, for the trigonometric functions differing successively by 45 degrees, that is,

$$e_1 = e_0 \sin q\,\vartheta$$

$$\frac{e_1 + e_2}{\sqrt{2}} = e_0 \sin\left(q\,\vartheta + \frac{\pi}{4}\right)$$

$$e_2 = e_0 \cos q\,\vartheta = e_0 \sin\left(q\,\vartheta + \left(\frac{\pi}{2}\right)\right.$$

$$\frac{e_2 - e_1}{\sqrt{2}} = e_0 \cos\left(q\,\vartheta + \frac{\pi}{4}\right) = e_0 \sin\left(q\,\vartheta + \frac{3\pi}{4}\right)$$

the first curve of Fig. 4 so is the beginning of Fig. 3.

In waves traveling over a water surface, shapes like Fig. 4 can be observed.

For the purpose of illustration, however, in Figs. 3 and 4 the oscillations are shown far longer than usually occur: the value: $q = 2620$, corresponds to a frequency: $N = 418$ cycles, while traveling waves are more common of frequencies from 100 to 10,000 times as high.

20. A specially interesting traveling wave is the wave in which:

$$f = w$$

since in this wave the time decrement of the first main wave and its reflected wave vanishes:

$$\varepsilon^{-(w-f)t} = 0$$

that is, the first main wave and its reflected wave are not transient, but permanent, that is, alternating waves, and the equations of the first main wave give the equation of the alternating-current circuit with distributed r, L, g, C, which appears as a special case of a traveling wave.

Since in this case, the frequency, and so the value of q is low, and comparable with w and f, the approximations made in the previous discussion of the traveling wave are not permissible, but the general equations have to be used.

Substituting therefore in (29) and (30):

$$f = w$$

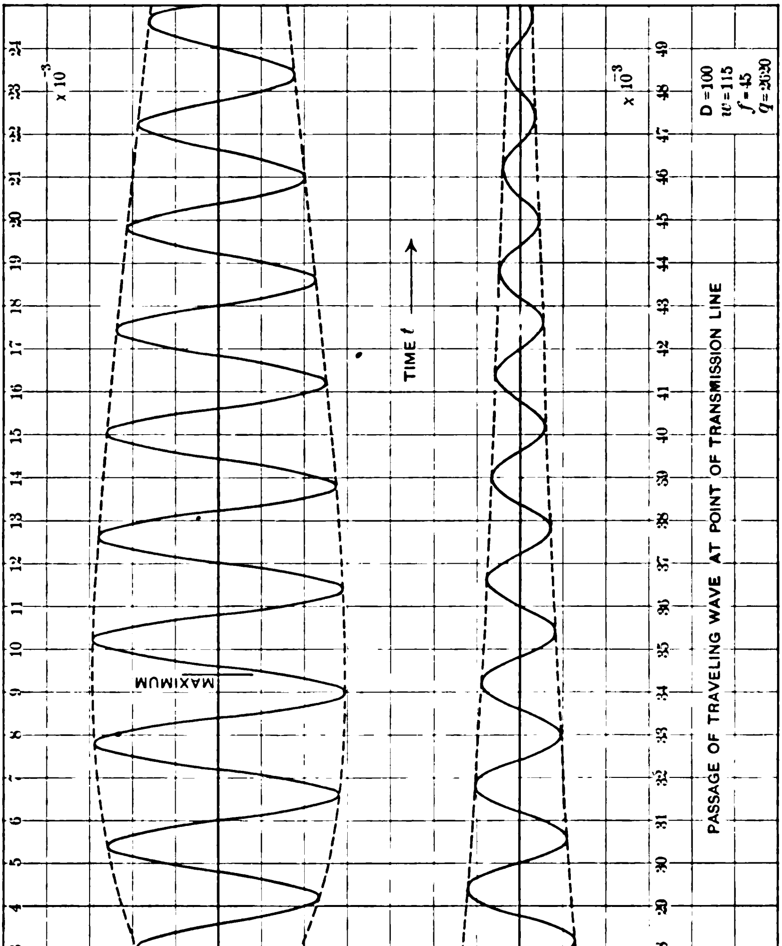

+30
+20
+10
-10
-20
-30
i
-20
+10
0
-10
-20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
$\times 10^{-3}$
26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
$\times 10^{-3}$
MAXIMUM
TIME t →
PASSAGE OF TRAVELING WAVE AT POINT OF TRANSMISSION LINE
D = 100
w = 115
f = 45
q = 2030

Fig. 3

gives:

$$i = [\varepsilon^{-hu} \{C_1 \cos (qt - ku) + C_1' \sin (qt - ku)\} - \varepsilon^{+hu} \{C_2 \cos (qt + ku) + C_2' \sin (qt + ku)\}] - \varepsilon^{-2wt} [\varepsilon^{-hu} \{C_4 \cos (qt + ku) + C_4' \sin (qt + ku)\} - \varepsilon^{+hu} \{C_3 \cos (qt - ku) + C_3' \sin (qt - ku)\}] \tag{75}$$

and:

$$e = [\varepsilon^{-hu} \{(c_1' C_1' - c_1 C_1) \cos (qt - ku) - (c_1' C_1 + c_1 C_1') \sin (qt - ku)\} + \varepsilon^{+hu} \{(c_1' C_2' - c_1 C_2) \cos (qt + ku) - (c_1' C_2 + c_1 C_2') \sin (qt + ku)\}] + \varepsilon^{-2wt} [\varepsilon^{-hu} \{(c_2' C_4' - c_2 C_4) \cos (qt + ku) - (c_2' C_4 + c_2 C_4') \sin (qt + ku)\} + \varepsilon^{+hu} \{(c_2' C_3' - c_2 C_3) \cos (qt - ku) - (c_2' C_3 + c_2 C_3') \sin (qt - ku)\}] \tag{76}$$

In these equations of current *i* and voltage *e*, the first term represents the usual equations of the distribution of alternating current and voltage in a long distance transmission line, and can by the substitution of complex quantities be reduced to the form usually given.

The second term is a transient term of the same frequency. That is:

In a long distance transmission line or other circuits of distributed *r*, *L*, *g*, *C*, when traversed by alternating current under an alternating impressed voltage, at a change of circuit conditions a transient term of fundamental frequency may appear, which has the time decrement, that is, dies out at the rate:

$$\varepsilon^{-2wt} = \varepsilon^{-\left(\frac{r}{L} + \frac{g}{C}\right)t}$$

It is interesting to note, that here the general equations of alternating-current long distance transmission appear as a special case of the equation of the traveling wave, and indeed can be considered as a section of a traveling wave, in which the acceleration constant *f* equals the exponential decrement *w*, and the attenuating constant α of the usual transmission line equation is the constant *h*; the wave length constant β is the constant *k*.

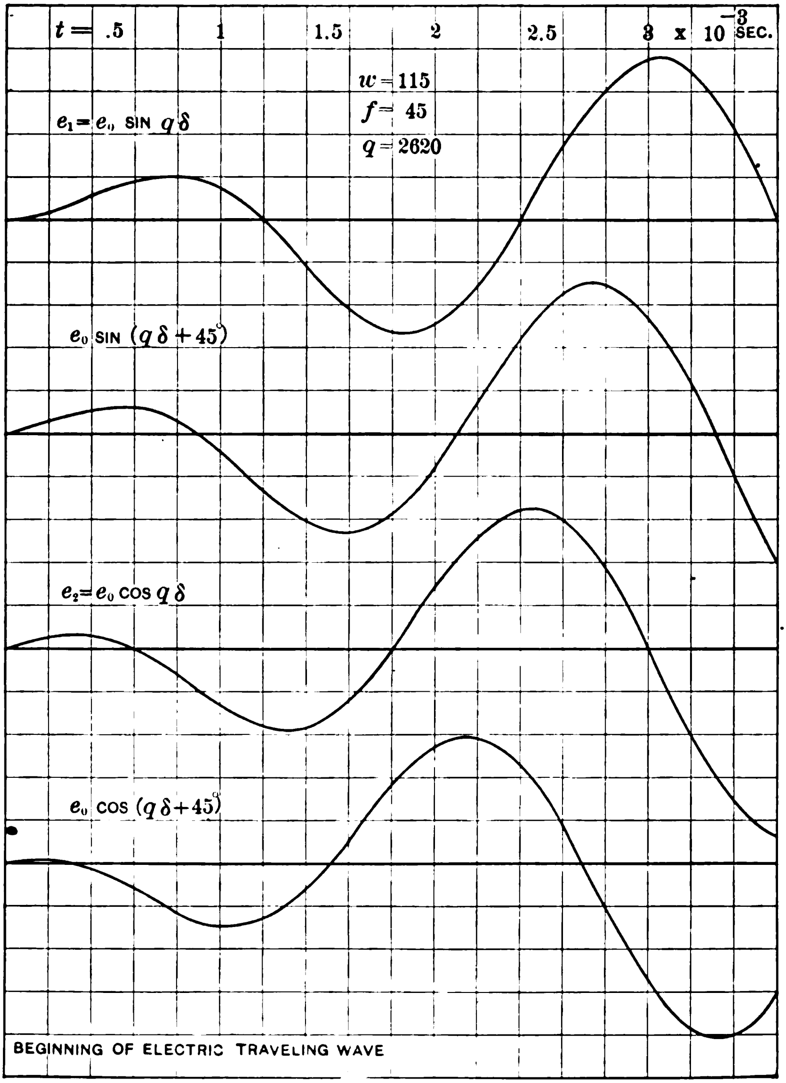

t = .5 1 1.5 2 2.5 3 x 10^-3 SEC.
w = 115
f = 45
q = 2620
e₁ = e₀ sin qδ
e₀ sin (qδ + 45°)
e₂ = e₀ cos qδ
e₀ cos (qδ + 45°)
BEGINNING OF ELECTRIC TRAVELING WAVE

FIG. 4

V. FREE OSCILLATIONS.

21. The general equations of the electric circuit (29) and (30), contain 8 terms: 4 waves, 2 main waves and their reflected waves, and each wave consists of a sine term and a cosine term.

The equations contain 5 constants:

The frequency constant q
The wave length constant k
The time attenuation constant w
The distance attenuation constant k
The time acceleration constant f

of which the time attenuation w is a constant of the circuit, independent of the character of the wave.

By the value of the acceleration constant f, waves may be subdivided into:

$f = 0$: standing waves,

$w > f > 0$: traveling waves,

$f = w$: alternating, current and voltage waves.

The general equations contain 8 integration constants C and C', which have to be determined by the terminal conditions of the problem.

Upon the values of these integration constants C and C' largely depends the difference between the phenomena occurring in electric circuits, as those due to direct currents or pulsating currents, alternating currents, oscillating currents, inductive discharges, etc., and the study of the *terminal conditions* is of the foremost importance.

Free oscillations are understood as the transient phenomena occurring in an electric circuit or part of the circuit, to which neither electric energy is supplied by some outside source, nor electric energy abstracted therefrom.

Free oscillations thus are the transient phenomena resulting from the dissipation of the energy stored in the electric field of the circuit, or inversely, the accumulation of the energy of the electric field, and their appearance so presupposes the possibility of energy storage in more than one form, so as to allow an interchange or surge of energy between its different forms, electromagnetic and electrostatic energy. Free oscillations occur only in circuits containing capacity C as well as inductance L.

The absence of energy supply or obstruction so defines the free oscillations by the conditions, that the power $p = e\,i$ at the two ends of the circuit or section of the circuit must be zero at all times, or the circuit must be closed upon itself.

With a circuit of uniformly distributed constants, the latter case is not realized, but is of foremost importance in a complex circuit, that is, a circuit comprising sections of different constants.

Representing then the two ends of the electric circuit by $u = 0$ and $u = l$, that is, counting the distance from one end of the circuit, the condition of a free oscillation is:

$$u = 0: \qquad p = 0:$$
$$u = l: \qquad p = 0.$$

since $p = e\,i$, this means that at $u = 0$ and $u = l$, either e or i must be zero.

This gives 4 sets of terminal conditions:

1. $e = 0$ at $u = 0$; $i = 0$ at $u = l$.
2. $i = 0$ at $u = 0$; $e = 0$ at $u = l$.
3. $e = 0$ at $u = 0$; $e = 0$ at $u = l$.
4. $i = 0$ at $u = 0$; $i = 0$ at $u = l$.

Case 2 represents the same condition as 1, merely with the distance u counting from the other end of the circuit: a line open at one end, grounded at the other end. Case 3 represents a circuit open at both ends, and Case 4 a circuit grounded at both ends.

Substituting these terminal conditions into the general equations it follows:

$$h = 0$$

that is, the *free oscillation of a circuit is a standing wave.*

And also:

$$k\,l = \frac{(2\,n+1)\,\pi}{2} \tag{77}$$

if $e = 0$ at one, $i = 0$ at the other end of the circuit, and

$$k\,l = n\,\pi \tag{78}$$

if either $e = 0$ at both ends of the circuit, or $i = 0$ at both ends of the circuit.

From (77) it follows, that

$$k\,l = \frac{\pi}{2},$$

or an *odd* multiple thereof. That is, the longest wave which can exist in the circuit, is that which makes the circuit a quarter wave length. Besides this fundamental wave, all its odd multiples can exist. Such an oscillation may be called a *quarter wave oscillation.*

The oscillation of a circuit, which is open at one end, grounded at the other end, is a quarter wave oscillation, which can contain only the odd harmonics of the fundamental wave of oscillation.

From (78) it follows, that

$$k\,l = \pi$$

or a multiple thereof. That is, the longest wave, which can exist in such a circuit, is that wave, which makes the circuit a half wave length. Besides this fundamental wave, all its multiples, odd as well as even, can exist. Such an oscillation may be called a *half wave oscillation.*

The oscillations of a circuit which is open at both ends, or grounded at both ends, is a half wave oscillation, and a half wave oscillation can also contain the even harmonics of the fundamental wave of oscillation, and so also the constant term, for $n = 0$ in (78).

It is interesting to note, that in the half wave oscillation of a circuit, we have a case of a circuit, in which *even* higher harmonics exist, and the electromotive force and current wave are not symmetrical.

22. From $h = 0$ follows, by equation:

$$f = 0, \quad \text{if:} \quad k^2 > L\,C\,m^2,$$

and:

$$q = 0, \quad \text{if:} \quad k^2 < L\,C\,m^2,$$

The smallest value of k, which can exist, is, by equation (77):

$$k = \frac{\pi}{2\,l}$$

and, as discussed in paragraph (15), this value in high potential high power circuits usually is very much larger than $L\,C\,m^2$, so that the case: $q = 0$, is realized only in extremely long circuits, as long distance telephone or submarine cable, but not in transmission lines, and the first case: $f = 0$, is mainly of importance.

Substituting therefore: $h = 0$ and $f = 0$, dropping terms of higher order, and rearranging, finally gives the

Equations of the Free Oscillation:

$$\left.\begin{aligned} i &= \Sigma A\, \varepsilon^{-wt} \left\{\cos(qt - ku - \gamma) \pm \cos(qt + ku - \gamma)\right\} \\ e &= \sqrt{\frac{L}{C}}\, \Sigma A\, \varepsilon^{-wt} \left\{\cos(qt - ku - \gamma) \mp \cos(qt + ku - \gamma)\right\} \end{aligned}\right\} \qquad (79)$$

While the free oscillation of a circuit is a standing wave, the general standing wave, as represented by equations (59) and (60), with 4 integration constants A_1, A_1', A_2, A_2', is not necessarily a free oscillation.

To be a free oscillation, the power $e\,i$, that is, either e or i, must be zero at two points of the circuit, the ends of the circuit or section of circuit, which oscillates.

This gives:

$$A_1^2 + A_1'^2 = A_2^2 + A_2'^2$$

as the condition, which must be fulfilled between the integration constants, to make a standing wave a free oscillation, and as can easily be shown.

If the integration constants of a standing wave fulfil the conditions:

$$A_1^2 + A_1'^2 = A_2^2 + A_2'^2 = B^2$$

the circuit of this wave contains points u_1, distant from each other by half a wave length, at which $e = 0$, and points u_2, distant from each other by half a wave length, at which $i = 0$, and the points u_2 are intermediate between the points u_1, that is, distant therefrom by one-quarter wave length. Any section of the circuit, from a point u_1 or u_2 to any other point u_1 or u_2 then is a free oscillating circuit.

In the free oscillation of the circuit, either the circuit is bounded by one point u_1 and one point u_2, that is, the voltage is zero at one end, and the current zero at the other end of the circuit, and the circuit then is a quarter wave or an odd multiple thereof, or the circuit is bounded by two points u_1, or by two points u_2, and then the voltage is zero at both ends of the circuit, or the current is zero at both ends of the circuit, and in either case the circuit is one half wave or a multiple thereof.

23. Choosing one of the points u_1 or u_2 as starting point of the distance, and introducing again the velocity of propagation as unit distance:

$$\lambda = \sigma u$$

$$\sigma = \sqrt{L C}$$

and denoting:

$$\left.\begin{aligned} \phi &= \frac{2\pi}{\lambda_0} t \\ \omega &= \frac{2\pi}{\lambda_0} \lambda = \frac{2\pi\sqrt{L C}}{\lambda_0} u \end{aligned}\right\} \qquad (80)$$

That is, representing a complete cycle of the fundamental frequency, or complete wave in time, by $\phi = 2\pi$, and a complete wave in space, by $\omega = 2\pi$.

A. *Quarter Wave Oscillation*:

(*a*) $e = 0$ at $u = 0$ (or: $\omega = 0$):

$$\left.\begin{aligned} e &= \varepsilon^{-wt} \sum_0^\infty {}_n B_n \sin (2n+1)\, \omega \sin [(2n+1)\, \phi + \gamma_n] \\ i &= \sqrt{\frac{C}{L}}\, \varepsilon^{-wt} \sum_0^\infty {}_n B_n \cos (2n+1)\, \omega \cos [(2n+1)\, \phi + \gamma_n] \end{aligned}\right\} \qquad (81)$$

(*b*) $i = 0$ at $u = 0$ (or: $\omega = 0$):

$$\left.\begin{aligned} e &= \varepsilon^{-wt} \sum_0^\infty {}_n B_n \cos (2n+1)\, \omega \cos [(2n+1)\, \phi + \gamma_n] \\ i &= \sqrt{\frac{C}{L}}\, \varepsilon^{-wt} \sum_0^\infty {}_n B_n \sin (2n+1)\, \omega \sin [(2n+1)\, \phi + \gamma_n] \end{aligned}\right\} \qquad (82)$$

B. *Half-Wave Oscillation*:

(*a*) $e = 0$ at $u = 0$ (or: $\omega = 0$):

$$\left.\begin{aligned} e &= \varepsilon^{-wt} \sum_0^\infty {}^n B_n \sin n\,\omega \sin (n\,\phi + \gamma_n) \\ i &= \sqrt{\frac{C}{L}}\, \varepsilon^{-wt} \sum_0^\infty {}^n B_n \cos n\,\omega \cos (n\,\phi + \gamma_n) \end{aligned}\right\} \quad (83)$$

(*b*) $i = 0$ at $u = 0$ (or: $\omega = 0$):

$$\left.\begin{aligned} e &= \varepsilon^{-wt} \sum_0^\infty {}^n B_n \cos n\,\omega \cos (n\,\phi + \gamma_n) \\ i &= \sqrt{\frac{C}{L}}\, \varepsilon^{-wt} \sum_0^\infty {}^n B_n \sin n\,\omega \sin (n\,\phi + \gamma_n) \end{aligned}\right\} \quad (84)$$

where:

$$\left.\begin{aligned} \phi &= \frac{2\pi}{\lambda_0} t \\ \omega &= \frac{2\,\pi \sqrt{L\,C}}{\lambda_0} u \end{aligned}\right\} \quad (85)$$

$$\left.\begin{aligned} \lambda_0 &= 4\,l \sqrt{L\,C} \text{ in a quarter-wave,} \\ &= 2\,l \sqrt{L\,C} \text{ in a half-wave oscillation.} \end{aligned}\right\} \quad (86)$$

and:

$$\varepsilon^{-wt} = \varepsilon^{-\frac{\lambda_0 w}{2\pi}\phi} \quad (87)$$

λ_0 is the wave length, and thus l/λ_0 the frequency, of the fundamental wave, with the velocity of propagation as distance unit.

It is interesting to note, that the time decrement of the free oscillation, ε^{-wt}, is the same for all frequencies and wave lengths, and that the relative intensity of the different harmonic components of the oscillation, and thereby the wave shape of the oscillation, remains unchanged during the decay of the oscillation.

This result, analogous to that found in the discussion on traveling waves, obviously is based on the assumption, that the constants of the circuit do not change with the frequency. This, however, is not perfectly true; at very high frequencies, r increases, due to unequal current distribution in the conductor, and L slightly decreases hereby. g increases by the energy losses resulting from brush discharges and from electrostatic radiation, etc., so that in general, at very high frequency, an increase of r/L and g/C, and so of w may be expected, that is, a greater rapidity of the dying out of very high harmonics. This would result in smoothing out the wave shape with increasing decay, that is, making it more approach the fundamental and its lower harmonics.

24. The equations of a free oscillation of a circuit, as quarter wave or half wave, still contain the pairs of integration constants B_n and γ_n, representing respectively the intensity and the phase of the nth harmonic.

These pairs of integration constants are determined by the terminal conditions of time, that is, they depend upon the amount and the distribution of the stored energy of the circuit at the starting moment of the oscillation. or in other words, on the distribution of current and voltage at $t = 0$.

The voltage e_0 and current i_0, at time $t = 0$, can be expressed as an infinite series of trigonometric functions of the distance u, that is, the distance angle ω, or a Fourier series of such character as also to fulfil the terminal conditions in space, as discussed above, that is, $e = 0$ respectively $i = 0$ at the ends of the circuit.

The voltage and current distribution in the circuit, at the starting moment of the oscillation, $t = 0$ respectively $\phi = 0$, so determines the integration constants in the usual manner.

25. As an instance the discharge of a transmission line may be considered:

A circuit of length l is charged to a uniform voltage E, while no current passes in the circuit. This circuit then is grounded at one end, while the other end remains insulated.

Let the distance be counted from the grounded end, and the time from the moment of grounding.

The terminal conditions then are:

(a) $\omega = 0$: $e = 0$
$\omega = \pi/2$: $i = 0$

(b) at $\phi = 0$:
$e = 0$ for: $\omega = 0$; $e = E$ for: $\omega \pm 0$
$i = 0$ for: $\omega \pm 0$; $i =$ indefinite for: $\omega = 0$.

The distribution of voltage e_0 and current i_0 in the circuit, at the starting moment $\phi = 0$, can be expressed by the Fourier series, and it is,

$$e = \frac{4}{\pi} \frac{E}{} \varepsilon^{-wt} \sum_{1}^{\infty} {}_n \frac{\sin (2n+1) \omega \cos (2n+1) \phi}{2n+1}$$

$$i = \frac{4\,E}{\pi} \sqrt{\frac{C}{L}} \varepsilon^{-ut} \sum_{1}^{\infty} {}_n \frac{\cos (2n+1) \omega \sin (2n+1) \phi}{2n+1}$$

Choosing the constants:

$l = 120$ miles
$r = 0.41$ ohms
$L = 1.95 \times 10^{-3}\, h$
$g = 0.25 \times 10^{-6}$ mho
$C = 0.0162 \times 10^{-6}\, f$
$E = 40{,}000$ volts.

$$e = 51{,}000\, \varepsilon^{-.0485\phi} \left\{ \sin \omega \cos \phi + \tfrac{1}{3} \sin 3\,\omega \cos 3\,\phi + \tfrac{1}{5} \sin 5\,\omega \cos 5\,\phi + \ldots \right\} \text{ volts}$$

$$i = 147.2\, \varepsilon^{-0.485\phi} \left\{ \cos \omega \sin \phi + \tfrac{1}{3} \cos 3\,\omega \sin 3\,\phi + \tfrac{1}{5} \cos 5\,\omega \sin 5\,\phi + \ldots \right\} \text{ amperes.}$$

VI. TRANSITION POINTS AND THE COMPLEX CIRCUIT.

26. The discussions of standing waves and free oscillations, and traveling waves, in the preceding, directly apply only to simple circuits, that is, circuits comprising a conductor of uniformly distributed constants r, L, g, C. Industrial electric circuits, however, never are simple circuits, but are always complex circuits comprising sections of different constants, generator, transformer, transmission lines and load; and a simple circuit is realized only by a section of a circuit, as a transmission line or a high potential transformer coil, which is cut off at both ends from the rest of the circuit, either by open circuiting: $i = 0$, or by short circuiting: $e = 0$. Approximately, the simple circuit is realized by a section of a complex circuit, connecting to other sections of very different constants, so that the ends of the circuit can, approximately, be considered as reflection points. For instance, an underground cable, of low L and high C, when connected to a large reactive coil, of high L and low C, may, approximately, at its ends be considered as having reflec-

tion points: $i = 0$. A high potential transformer coil, of high L and low C, when connected to a cable, of low L and high C, may at its ends be considered as having reflection points: $e = 0$. That is, in other words, in the first case the reactive coil may be considered as stopping the flow of current, in the latter case the cable considered as short circuiting the transformer. This approximation however, while frequently relied upon in engineering practice, and often permissible for the circuit section in which the transient phenomenon originates, is not permissible in considering the effect of the phenomenon on the adjacent sections of the circuit. For instance, in the first case above mentioned, a transient phenomenon in an underground cable connected to a high reactance: the current and voltage in the cable may approximately be represented by considering the reactive coil as a reflection point, that is, an open circuit, since only a small current enters the reactive coil. Such a small current, entering the reactive coil, may however, give a very high and destructive voltage in the reactive coil, due to its high L, and so in the circuit beyond the reactive coil. In the investigation of the effect of a transient phenomenon originating in one section of a complex circuit—as an oscillating arc on an underground cable—on other sections of the circuit—as the generating station—even a very great change of circuit constants, cannot be considered as a reflection point. Since this is the most important case met in industrial practice, as disturbances originating in one section of a complex circuit usually develop their destructive effects in other sections of the circuit, the investigation of the general problem of a complex circuit comprising sections of different constants becomes necessary. This requires the investigation of the changes occurring in an electric wave, and its equations, when passing over a transition point from one circuit or section of a circuit into another section of different constants.

The equations (29) and (30), while most general, are less convenient for studying the transition of a wave from one circuit to another circuit, of different constants, and since in industrial high voltage circuits at least for waves originating in the circuits, q and k are very large compared with f and h, as discussed before, f and h may be neglected compared with q and k. This gives the equations (45) and (46), or, substituting (47) and reversing the sign of λ, that is, counting the distance in opposite direction:

$$\begin{aligned} i = \varepsilon^{-wt} \{ & \varepsilon^{-f(\lambda-t)} [C_1 \cos q (\lambda - t) + C_1' \sin q (\lambda - t)] \\ & - \varepsilon^{+f(\lambda+t)} [C_2 \cos q (\lambda + t) + C_2' \sin q (\lambda + t)] \\ & + \varepsilon^{+f(\lambda-t)} [C_3 \cos q (\lambda - t) + C_3' \sin q (\lambda - t)] \\ & - \varepsilon^{-f(\lambda+t)} [C_4 \cos q (\lambda + t) + C_4' \sin q (\lambda + t)] \} \end{aligned} \qquad (88)$$

where the constants are given by equations (37) to (43).

$$\begin{aligned} e = \sqrt{\frac{L}{C}}\, \varepsilon^{-wt} \{ & \varepsilon^{-f(\lambda-t)} [C_1 \cos q (\lambda - t) + C_1' \sin q (\lambda - t)] \\ & + \varepsilon^{+f(\lambda+t)} [C_2 \cos q (\lambda + t)) + C_2' \sin q (\lambda + t)] \\ & + \varepsilon^{+f(\lambda-t)} [C_3 \cos q (\lambda - t) + C_3' \sin q (\lambda - t)] \\ & + \varepsilon^{-f(\lambda+t)} [C_4 \cos q (\lambda + t) + C_4' \sin q (\lambda + t)] \} \end{aligned} \qquad (89)$$

Substituting:

$$\left. \begin{aligned} C_1^2 + C_2'^2 &= A^2 \\ C_2^2 + C_2'^2 &= B^2 \\ C_3^2 + C_3'^2 &= C^2 \\ C_4^2 + C_4'^2 &= D^2 \end{aligned} \right\} \qquad (90)$$

$$\left. \begin{aligned} \frac{C_1'}{C_1} &= \tan \alpha \\ \frac{C_2'}{C_2} &= \tan \beta \\ \frac{C_3'}{C_3} &= \tan \gamma \\ \frac{C_4'}{C_4} &= \tan \delta \end{aligned} \right\} \qquad (91)$$

gives these equations in the form:

$$\begin{aligned} i = \varepsilon^{-wt} \{ & A\, \varepsilon^{-f(\lambda-t)} \cos [q (\lambda - t) - \alpha] - B\, \varepsilon^{+f(\lambda+t)} \cos [q (\lambda + t) - \beta] \\ & + C\, \varepsilon^{+f(\lambda-t})\cos [q (\lambda - t) - \gamma] - D\, \varepsilon^{-f(\lambda+t)} \cos [q(\lambda + t) - \\ & \delta] \} \end{aligned} \qquad (92)$$

$$e = \sqrt{\frac{L}{C}}\,\varepsilon^{-ut}\,\{A\,\varepsilon^{-f(\lambda-t)}\cos[q(\lambda-t)-\alpha] + B\,\varepsilon^{+f(\lambda+t)}\cos[q(\lambda+t)-\beta]$$
$$+ C\,\varepsilon^{+f(\lambda-t)}\cos[q(\lambda-t)-\gamma] + D\,\varepsilon^{-f(\lambda+t)}\cos[q(\lambda+t)-\delta]\} \tag{93}$$

In these equations, λ is the distance co-ordinate, using the velocity of propagation as unit distance, and at a transition point from one circuit to another, where the circuit constants change, the velocity of propagation also changes, and so, for the same time, constants f and q, h and k, also change, and so ku, but transformed to the distance variable λ, $ku = q\,\lambda$ remains the same. That is, by introducing the distance variable λ, the distance can be measured throughout the entire circuit, and across transition points, at which the circuit constants change, and the same equations apply throughout the entire circuit. In this case however, in any section of the circuit,

$$\left.\begin{aligned}\lambda &= \sigma_i\,u\\ &= u\,\sqrt{L_i\,C_i}\end{aligned}\right\} \tag{94}$$

where L_i and C_i are the inductance and the capacity, respectively, of the section i of the circuit, per unit length; for instance, per mile.

That is, in a complex circuit, the time variable t is the same throughout the entire circuit, or in other words, the frequency of oscillation, as represented by q, and the rate of decay of the oscillation, as represented by the exponential function of time must be the same throughout the entire circuit. Not so however with the distance variable u: the wave length of the oscillation, and its rate of building up or down, along the circuit, need not be the same, and usually are not, but in some sections of the circuit, the wave length may be far shorter, as in coiled circuits in transformers, due to the higher L, or in cables, due to the higher C. To extend the same equations over the entire complex circuit, it therefore becomes necessary to substitute for the distance variable u another distance variable λ of such character, that the wave length has the same value in all sections of the complex circuit. As the wave length of the section i is $\frac{1}{\sqrt{L_i\,C_i}}$, this is done by changing the unit distance by the factor: $\sigma_i = \sqrt{L_i\,C_i}$. The distance unit of the new distance variable λ then is the distance traversed by the wave in unit time, hence different in linear measure, for the different sections of the circuit, but offers the advantage of carrying the distance measurements across the entire circuit and over transition points, by the same distance variable λ.

This means, that the length u_i of any section i of the complex circuit is expressed by the length: $\lambda_i = \sigma_i u_i$.

The introduction of the distance variable λ also has the advantage, that in the determination of the constants r, L, g, C, of the different sections of the circuit, different linear distance measurements u may be used. For instance, in the transmission line, the constants may be given per mile, that is, the mile used as unit length, while in a high potential transformer coil as unit of length u may be used the turn, or the coil, or the total transformer, so that the actual linear length of conductor may be unknown. For instance, choosing the total length of conductor in the high potential transformer as unit length, then the length of the transformer winding in the velocity measure λ is, $\lambda_0 = \sqrt{L_0 C_0}$ where L_0 = total inductance, C_0 = total electrostatic capacity of transformer.

The introduction of the distant variable λ permits the representation, in the circuit, of apparatus as reactive coils, etc., in which one of the constants is very small compared with the other, and so is usually neglected, and the apparatus considered as " massed inductance " etc., and allows the investigation of the effect of the distributed capacity of reactive coils and similar matters, by representing the reactive coil as a finite (frequently quite long) section of the circuit.

27. Let $\lambda_0, \lambda_1, \lambda_2, \ldots \lambda_n$ be a number of transition points, at which the circuit constants change, and the quantities may be denoted by index 1 in the section from λ_0 to λ_1, by index 2 in the section from λ_1 to λ_2, etc.

At $\lambda = \lambda_1$, it then must be: $i_1 = i_2$, $e_1 = e_2$; thus, substituting $\lambda = \lambda_1$ into equations (92) and (93), and equating, gives two identities, from which it follows:

$$w_2 \pm f_2 = w_1 \pm f_1 \qquad (95)$$

that is, since $w_2 \pm w_1$, only one of the two component waves can exist. Since these two waves differ from each other only by the sign of f, by assuming that f may be either positive or negative, we can select either one of the two waves, and the equations (92) and (93), or (88) and (89) so assume the simpler forms:

$$i = \varepsilon^{-(w+f)t} \left\{ A\, \varepsilon^{+f\lambda} \cos [q\, (\lambda - t) - \alpha] - B\, \varepsilon^{-f\lambda} \cos [q\, (\lambda + t) - \beta] \right\}$$

$$e = \sqrt{\frac{L}{C}}\, \varepsilon^{-(w+f)t} \left\{ A\, \varepsilon^{+f\lambda} \cos [q(\lambda - t) - \alpha] + B\, \varepsilon^{-f\lambda} \cos [q(\lambda + t) - \beta] \right\} \tag{96}$$

$$i = \varepsilon^{-(w+f)t} \left\{ \varepsilon^{+f\lambda} [A \cos q\, (\lambda - t) + B \sin q\, (\lambda - t)] - \varepsilon^{-f\lambda} [C \cos q\, (\lambda + t) + D \sin q\, (\lambda + t)] \right\}$$

$$e = \sqrt{\frac{L}{C}}\, \varepsilon^{-(w+f)t} \left\{ \varepsilon^{+f\lambda} [A \cos q\, (\lambda - t) + B \sin q\, (\lambda - t)] + \varepsilon^{-f\lambda} [C \cos q\, (\lambda + t) + D \sin q\, (\lambda + t)] \right\} \tag{97}$$

where f may be positive or negative.

It is then:

$$w_1 + f_1 = w_2 + f_2 = w_3 + f_3 = \; . \; . \; . \; = w_n + f_n = m_0 \tag{98}$$

where w_1, w_2, w_3, etc., w_n, are the time constants of the individual sections, $\frac{1}{2} \left(\frac{r}{L} + \frac{g}{C} \right)$, and m_0 may be called the *resultant time decrement of the complex circuit.*

The identities: $i_1 = i_2$ and $e_1 = e_2$ for $\lambda = \lambda_1$, resolved for $\cos qt$ and $\sin qt$, then give 4 equations, by which the integration constants A, B, α, β, or A, B, C, D, of one section of the circuit are determined by those of the adjoining section, by the expressions:

$$\left.\begin{aligned}
A_2 &= \varepsilon^{-f_2\lambda_1} \left\{ a_1\, \varepsilon^{+f_1\lambda_1} A_1 + b_1\, \varepsilon^{-f_1\lambda_1} (C_1 \cos 2\, q\, \lambda_1 + D_1 \sin 2\, q\, \lambda_1) \right\} \\
B_2 &= \varepsilon^{-f_2\lambda_1} \left\{ a_1\, \varepsilon^{+f_1\lambda_1} B_1 + b_1\, \varepsilon^{-f_1\lambda_1} (C_1 \sin 2\, q\, \lambda_1 - D_1 \cos 2\, q\, \lambda_1) \right\} \\
C_2 &= \varepsilon^{+f_2\lambda_1} \left\{ a_1\, \varepsilon^{-f_1\lambda_1} C_1 + b_1\, \varepsilon^{+f_1\lambda_1} (A_1 \cos 2\, q\, \lambda_1 - B_1 \sin 2\, q\, \lambda_1) \right\} \\
D_2 &= \varepsilon^{+f_2\lambda_1} \left\{ a_1\, \varepsilon^{-f_1\lambda_1} D_1 + b_1\, \varepsilon^{+f_1\lambda_1} (A_1 \sin 2\, q\, \lambda_1 - B_1 \cos 2\, q\, \lambda_1) \right\}
\end{aligned}\right\} \tag{99}$$

where:

$$\left.\begin{aligned} a_1 &= \frac{c_1 + c_2}{2\,c_2} \\ b_1 &= \frac{c_1 - c_2}{2\,c_2} \end{aligned}\right\} \quad (100)$$

$$\left.\begin{aligned} c_1 &= \sqrt{\frac{L_1}{C_1}} \\ c_2 &= \sqrt{\frac{L_2}{C_2}}. \end{aligned}\right\} \quad (101)$$

28. The general equation of current and voltage in a complex circuit consists of two terms, a main wave and its reflected wave.

The factor $\varepsilon^{-(w+f)t} = \varepsilon^{-m_0 t}$ represents the time decrement, or the decrease of the intensity of the wave with the time, and as such is the same throughout the entire circuit. In an isolated section, of time constant w, the time decrement, was found however as ε^{-wt}. That is, with the decrement ε^{-wt}, the wave dies out in an isolated section at the rate at which its stored energy is dissipated by the power lost in resistance and conductance. In a section of the circuit connected to other sections, the time decrement $\varepsilon^{-m_0 t}$ does not correspond to the power dissipation in the section, that is, the wave does not die out in each section at the rate as given by the power consumed in this section, or in other words, power transfer occurs from section to section, during the oscillation of a complex circuit.

If f is negative, m_0 is less than w, and the wave dies out in that particular section at a lesser rate than corresponds to the power consumed in the section, or in other words, in this section of the complex circuit, more power is consumed by r and g than is supplied by the decrease of the stored energy, and this section so must receive energy from adjoining sections. Inversely, if f is positive, $m_0 > w$, and the wave dies out more rapidly in that section than its stored energy is consumed by r and g; that is, a part of the stored energy of this section is transferred to the adjoining sections, and only a part—occasionally a very small part—dissipated in the section, and this section acts as a store of energy for supplying the other sections of the system.

The constant f of the circuit may be called *energy transfer constant*, and positive f means transfer of energy from the section to the rest of the circuit, and negative f means reception of energy from other sections.

This explains the vanishing of f in a standing wave of a uniform circuit, due to the absence of energy transfer, and its presence in the equations of the traveling wave, in which energy is transferred along the circuit, and in the alternating current equations.

It follows herefrom, that in a complex circuit, some of the f of the different sections must always be positive, some negative.

In addition to the time decrement, $\varepsilon^{-m_0 t}$, the waves in equations (96) and (97) also contain the distance decrement $\varepsilon^{+f\lambda}$ for the main wave, $\varepsilon^{-f\lambda}$ for the reflected wave. Negative f means a decrease of the main wave for increasing λ, or in the direction of propagation, and a decrease of the reflected wave for decreasing λ, that is, also in the direction of propagation, while positive f means increase of main wave as well as reflected wave, in the direction of propagation along the circuit. That is if f is negative, and the section so consumes more power than is given by its stored energy, and therefore receives power from the adjoining sections, the electric wave decreases, in the direction of its propagation, showing the gradual dissipation of the power received from adjoining sections. Inversely, if f is positive and the section so supplies power to adjoining sections, the electric wave increases in this section, in the direction of its propagation.

In other words, in a complex circuit, in sections of low power dissipation, the wave increases, and transfers power to sections of high power dissipation in which the wave decreases.

29. Introducing the resultant time decrement m_0 of the complex circuit, the equations of any section can be expressed by the resultant time decrement of the entire complex circuit, m_0, and the energy transfer constant of the individual section:

$$f = m_0 - w \tag{102}$$

in the form:

$$i = \varepsilon^{-m_0 t} \{\varepsilon^{+f\lambda}[A \cos q\,(\lambda - t) + B \sin q\,(\lambda - t)] - \varepsilon^{-f\lambda}[C \cos q\,(\lambda + t) + D \sin q\,(\lambda + t)]\} \quad . \tag{103}$$

$$e = \sqrt{\frac{L}{C}}\, \varepsilon^{-m_0 t} \{\varepsilon^{+f\lambda} [A \cos q (\lambda - t) + B \sin q (\lambda - t)] + \varepsilon^{-f\lambda} [C \cos q (\lambda + t) + D \sin q (\lambda + t)]\}$$

The constants A, B, C, D, are the integration constants, and are such as given by the terminal conditions of the problem, as by the distribution of current and voltage in the circuit at the starting moment, for $t = 0$, or at one particular point, as $\lambda = 0$.

The constants m_0 and q are dependent upon the circuit conditions: if the circuit is closed upon itself—as usually is the case with an electrical transmission or distribution circuit—and Λ the total length of the closed circuit, the equations must for $\lambda = \Lambda$ give the same values as for $\lambda = 0$, and therefore $q\Lambda$ must be a complete cycle or a multiple thereof: $2 n \pi$. That is:

$$q = \frac{2 n \pi}{\Lambda} \tag{104}$$

and the least value of q, or the fundamental frequency of oscillation, is:

$$q_0 = \frac{2\pi}{\Lambda} \tag{105}$$

and:

$$q = n q_0 \tag{106}$$

If the complex circuit is open at both ends, or grounded at both ends, and so performs a half wave oscillation, and $\Lambda_1 =$ total length of the circuit, it is:

$$\left.\begin{aligned} q_0 &= \frac{\pi}{\Lambda_1} \\ q &= n q_0 \end{aligned}\right. \tag{107}$$

and if the circuit is open at one end, grounded at the other end, so performing a quarter wave oscillation, and $\Lambda_2 =$ total length of circuit, it is:

$$\left.\begin{aligned} q_0 &= \frac{\pi}{2 \Lambda_2} \\ q &= (2 n - 1) q_0 \end{aligned}\right\} \tag{108}$$

If the length of the complex circuit is very great compared with the frequency of the oscillation, q_0 may have any value. That is, if the wave length of the oscillation is very short compared with the length of the circuit, any wave length, and so any frequency, may occur. With uniform circuits, as transmission lines, this latter case, that is, the response of the line to any frequency, can occur only in the range of very high frequencies. That is, even in a transmission line of several hundred miles length, the lowest frequency of free oscillation is fairly high, and frequencies, which are so high, compared with the fundamental frequency of the circuit, that, considered as higher harmonics thereof, they overlap, must be extremely high, of the magnitude of a million cycles. In complex circuits however, the fundamental frequency may be very much lower, and below machine frequencies, as the velocity of propagation $\frac{1}{\sqrt{L\,C}}$ may be quite low in some sections of the circuit, as the high potential coils of large transformers, and the presence of iron increases the inconstancy of L for high frequencies, so that in such a complex circuit, even at fairly moderate frequencies, of the magnitude of 10,000 cycles, the circuit may respond to any frequency.

The constant m_0 also is determined by the circuit constants. Upon m_0 depends the energy transfer constant of the circuit section, and thereby the rate of building up, in a section of low power consumption, or building down, in a section of high power consumption. In a closed circuit, however, passing around the entire circuit, the same values of e and i must again be reached, and the rates of building up and building down of the wave in the different sections, must therefore be such as to neutralize each other when carried through the entire circuit, that is, the total building up, through the entire complex circuit, must be zero. This gives an equation from which m_0 is determined, as a mean value of the time constants w_i of the individual circuit sections.

VII. Power and Energy of the Complex Circuit.

30. The free oscillation of a complex circuit differs from that of the uniform circuit, in that the former contains exponential functions of the distance λ, which represent the shifting, or transfer of power between the sections of the circuit.

Thus the general expression of one term or frequency of current and voltage in a section of a complex circuit is given by equation:

$$i = \epsilon^{-m_0 t} \{\epsilon^{+f\lambda} [A \cos q\,(\lambda - t) + B \sin q\,(\lambda - t)] - \epsilon^{-f\lambda} [C \cos q\,(\lambda + t) + D \sin q\,(\lambda + t)]\} \qquad (109)$$

$$e = \sqrt{\frac{L}{C}}\, \epsilon^{-m_0 t} \{\epsilon^{+ft} [A \cos q\,(\lambda - t) + B \sin q\,(\lambda - t)] + \epsilon^{-f\lambda} [C \cos q\,(\lambda + t) + D \sin q\,(\lambda + t)]\}$$

where:

$$q = n\, q_0$$

$$q_0 = \frac{2\pi}{\Lambda}$$

Λ = total length of circuits, expressed in the distance co-ordinate:

$$\lambda = \sigma u,$$

u being the distance co-ordinate of the circuit section in any measure, as miles, turns, etc., and r, L, g, C, the circuit constants per unit length of u, and:

$$\sigma = \sqrt{L\,C}$$

$$c = \sqrt{\frac{L}{C}}$$

$$w = \tfrac{1}{2}\left(\frac{r}{L} + \frac{g}{C}\right)$$ = time constant of circuit section,

$m_0 = w + f$ = resultant time decrement of complex circuit,
$f = m_0 - w$ = energy transfer constant of circuit section.

The instantaneous value of power at any point of the circuit, at any time t, is:

$$p = e\, i$$

$$= \sqrt{\frac{L}{C}}\, \epsilon^{-2 m_0 t} \{\epsilon^{+2f\lambda} [A \cos q(\lambda - t) + B \sin q(\lambda - t)]^2 - \epsilon^{-2f\lambda} [C \cos q\,(\lambda + t) + D \sin q\,(\lambda + t)]^2\}$$

$$= \tfrac{1}{2}\sqrt{\frac{L}{C}}\, \epsilon^{-2 m_0 t} \{[\epsilon^{+2f\lambda} (A^2 + B^2) - \epsilon^{-2f\lambda} (C^2 + D^2)] + [\epsilon^{+2f\lambda} (A^2 - B^2) \cos 2\,q\,(\lambda - t) - \epsilon^{-2f\lambda} (C^2 - D^2) \cos 2\,q\,(\lambda + t)] + 2\,[A\,B\, \epsilon^{+2f\lambda} \sin 2\,q\,(\lambda - t) - C\,D\, \epsilon^{-2f\lambda} \sin 2\,q\,(\lambda + t)]\} \qquad (110)$$

that is, the instantaneous value of power consists of a constant term, and terms of double frequency in $(\lambda - t)$ and $(\lambda + t)$, that is, in distance λ and time t.

Integrating (110) over a complete period in time, gives the *effective* or *mean value of power at any point* λ, as:

$$P = \tfrac{1}{2}\sqrt{\frac{L}{C}}\,\varepsilon^{-2m_0 t}\left\{\varepsilon^{+2f\lambda}(A^2+B^2) - \varepsilon^{-2f\lambda}(C^2+D^2)\right\}. \qquad (111)$$

That is, the instantaneous power at any time and any point of the circuit is the difference between the instantaneous power of the main wave, and that of the reflected wave.

The effective power at any point of the circuit is the difference between the effective power of the main wave and that of the reflected wave.

The effective power at any point of the circuit, gradually decreases in any section, with the resultant time decrement of the total circuit, $\varepsilon^{-2m_0 t}$, and varies gradually or exponentially with the distance λ, the one wave increasing, the other decreasing, so that at one point of the circuit or circuit section the effective power is zero. That is, this point of the circuit is a power node, or point across which no power flows. It is given by:

$$\left.\begin{aligned} &\varepsilon^{+2f\lambda}(A^2+B^2) = \varepsilon^{-2f\lambda}(C^2+D^2) \\ &\text{or:} \\ &\lambda = \frac{1}{4f}\lg\frac{C^2+D^2}{A^2+B^2} \end{aligned}\right\} \qquad (112)$$

The difference of power between two points of the circuit λ_1 and λ_2, that is, the power which is supplied or received (depending upon its sign) by a section $l = \lambda_2 - \lambda_1$ of the circuit, is given by equation (111) as:

$$P_0 = \tfrac{1}{2}\sqrt{\frac{L}{C}}\,\varepsilon^{-2m_0 t}\left\{(\varepsilon^{+2f\lambda_2} - \varepsilon^{+2f\lambda_1})(A^2+B^2) - (\varepsilon^{-2f\lambda_2} - \varepsilon^{-2f\lambda_1})(C^2+D^2)\right\} \qquad (113)$$

If $P_0 > 0$, this represents the power which is supplied by the section l to the adjoining sections of the circuit; if $P_0 < 0$, this is the power received by the section from the rest of the complex circuit.

If $f\lambda_2$ and $f\lambda_1$ are small quantities, the exponential function can be resolved in an infinite series, and all but the first term dropped, as of higher orders, or negligible, and this gives the approximate value:

$$\varepsilon^{\pm 2f\lambda_2} - \varepsilon^{\pm 2f\lambda_1} = \pm 2f(\lambda_2 - \lambda_1) = \pm 2fl$$

hence:

$$P_0 = fl\sqrt{\frac{L}{C}}\,\varepsilon^{-2m_0t}\left\{A^2 + B^2 + C^2 + D^2\right\} \tag{114}$$

That is, the power transferred from a section of length l, to the rest of the circuit, or received by the section from the rest of the circuit, is proportional to the length of the section, l, to its transfer constant f, and to the sum of the power of main wave and reflected wave.

31. The energy stored by the inductance, L, of a circuit element $d\lambda$, that is, in the magnetic field of the circuit, is:

$$d\eta_1 = \frac{L' i^2}{2}\,d\lambda$$

where L' = inductance per unit length of circuit, expressed by the distance co-ordinate λ.

Since L = inductance per unit length of circuit, of distance co-ordinate u, and $\lambda = \sigma u$, it is:

$$L' = \frac{L}{\sigma} = \frac{L}{\sqrt{LC}} = \sqrt{\frac{L}{C}}$$

hence:

$$d\eta_1 = \tfrac{1}{2}\sqrt{\frac{L}{C}}\,i^2\,d\lambda \tag{115}$$

In general, the circuit constants r, L, g, C, per unit length, $u = 1$, give, per unit length, $\lambda = 1$, the circuit constants:

$$\left.\begin{array}{l} \dfrac{r}{\sigma};\ \dfrac{L}{\sigma};\ \dfrac{g}{\sigma};\ \dfrac{C}{\sigma}; \\ \text{or:} \\ \dfrac{r}{\sqrt{LC}};\ \dfrac{L}{\sqrt{LC}} = \sqrt{\dfrac{L}{C}};\ \dfrac{g}{\sqrt{LC}};\ \dfrac{C}{\sqrt{LC}} = \sqrt{\dfrac{C}{L}} \end{array}\right\} \tag{116}$$

Substituting (109) in equation (115), expanded, and integrated over a complete period in time, gives the effective power stored in the magnetic field at point λ:

$$\frac{d\,H_1}{d\,\lambda} = \frac{1}{4}\sqrt{\frac{L}{C}}\,\varepsilon^{-2\,m_0 t}\left\{\left[\varepsilon^{+2l\lambda}\,(A^2+B^2)+\varepsilon^{-2l\lambda}\,(C^2+D^2)\right]-2\left[(AC-BD)\cos 2\,q\,\lambda+(A\,D-B\,C)\sin 2\,q\,\lambda\right]\right\} \tag{117}$$

and, integrated over one complete period of distance λ, or one complete wave length, this gives:

$$\frac{d\,H_1^0}{d\,\lambda} = \frac{1}{4}\sqrt{\frac{L}{C}}\,\varepsilon^{-2\,m_0 t}\left\{\left[\varepsilon^{+2l\lambda}\,(A^2+B^2)+\varepsilon^{-2l\lambda}\,(C^2+D^2)\right\}\right. \tag{118}$$

The energy stored by the inductance L, or in the magnetic field of the conductor, consists of:

A constant part:

$$\frac{d\,\eta_0}{d\,\lambda} = \frac{1}{4}\sqrt{\frac{L}{C}}\,\varepsilon^{-2\,m_0 t}\left\{\varepsilon^{+2l\lambda}\,(A^2+B^2)+\varepsilon^{-2l\lambda}\,(C^2+D^2)\right\} \tag{119}$$

A part which is a function of $(\lambda-t)$ and $(\lambda+t)$:

$$\frac{d\,\eta'}{d\,\lambda} = \frac{1}{4}\sqrt{\frac{L}{C}}\,\varepsilon^{-2\,m_0 t}\left\{\left[\varepsilon^{+2l\lambda}\,(A^2-B^2)\cos 2\,q\,(\lambda-t)+\varepsilon^{-2l\lambda}\,(C^2-D^2)\cos 2\,q\,(\lambda+t)\right]+2\left[A\,B\,\varepsilon^{+2l\lambda}\sin 2\,q\,(\lambda-t)+C\,D\,\varepsilon^{-2l\lambda}\sin 2\,q\,(\lambda+t)\right]\right\} \tag{120}$$

A part which is a function of the distance λ only, but not of time t:

$$-\frac{d\,\eta''}{d\,\lambda} = \frac{1}{2}\sqrt{\frac{L}{C}}\,\varepsilon^{-2\,m_0 t}\left\{(A\,C-B\,D)\cos 2\,q\,\lambda+(A\,D+B\,C)\sin 2\,q\,\lambda\right\} \tag{121}$$

And a part which is a function of time t only, but not of the distance λ:

$$-\frac{d\,\eta'''}{d\,\lambda} = \frac{1}{2}\sqrt{\frac{L}{C}}\,\varepsilon^{-2\,m_0 t}\left\{(A\,C+B\,D)\cos 2\,q\,t+(A\,D-B\,C)\sin 2\,q\,t\right\} \tag{122}$$

and the total energy of the electromagnetic field of circuit element $d\lambda$ at time t is:

$$\frac{d\,\eta_1}{d\,\lambda} = \frac{d\,\eta_0}{d\,\lambda} + \frac{d\,\eta'}{d\,\lambda} - \frac{d\,\eta''}{d\,\lambda} - \frac{d\,\eta'''}{d\,\lambda} \qquad (123)$$

The energy stored in the electrostatic field of the conductor, or by the capacity C, is given by:

$$d\,\eta_2 = \frac{C'\,e^2}{2}\,d\,\lambda$$

or, substituting (116):

$$\frac{d\,\eta_2}{d\,\lambda} = \tfrac{1}{2}\sqrt{\frac{C}{L}}\,e^2 \qquad (124)$$

and, substituting in (124) the value of e, from equation (109), gives the same expression as (123), except that the sign of the last two terms is reversed. That is:

The total energy of the electrostatic field of circuit element $d\lambda$ at time t is:

$$\frac{d\,\eta_2}{d\,\lambda} = \frac{d\,\eta_0}{d\,\lambda} + \frac{d\,\eta'}{d\,\lambda} + \frac{d\,\eta''}{d\,\lambda} + \frac{d\,\eta'''}{d\,\lambda} \qquad (125)$$

and, adding (123) and (125), gives the total stored energy of the electric field of the conductor:

$$\frac{d\eta}{d\lambda} = 2\left(\frac{d\,\eta_0}{d\,\lambda} + \frac{d\,\eta'}{d\,\lambda}\right) \qquad (126)$$

and, integrated over a complete period of time, this gives:

$$\frac{d\,H}{d\,\lambda} = 2\frac{d\,\eta_0}{d\,\lambda} = \tfrac{1}{2}\sqrt{\frac{L}{C}}\,\varepsilon^{-2m_0t}\left\{\varepsilon^{+2f\lambda}\left(A^2+B^2\right) + \varepsilon^{-2f\lambda}\left(C^2+D^2\right)\right\} \qquad (127)$$

The two last terms, $\frac{d\,\eta''}{d\,\lambda}$ and $\frac{d\,\eta'''}{d\,\lambda}$. represent the energy which is transferred, or pulsates, between the electromagnetic and the electrostatic field of the circuit; and the term $\frac{d\,\eta'}{d\,t}$ represents the alternating (or rather oscillating) component of stored energy.

The energy stored by the electric field in a circuit section l, between λ_1 and λ_2, is given by integrating $\frac{d\,H}{d\,\lambda}$ between λ_2 and λ_1, as:

$$H = \frac{1}{4\,f}\sqrt{\frac{L}{C}}\,\epsilon^{-2\,m_0 t}\,\left\{(\epsilon^{+2f\lambda_2} - \epsilon^{+2f\lambda_1})\,(A^2+B^2) - (\epsilon^{-2f\lambda_2} - \epsilon^{-2f\lambda_1})\right.$$
$$\left.(C^2+D^2)\right\} \qquad (128)$$
$$H = \tfrac{1}{2}\,l\sqrt{\frac{L}{C}}\,\epsilon^{-2\,m_0 t}\,\{A^2+B^2+C^2+D^2\}$$

Differentiating (128) after t, gives the power supplied by the electric field of the circuit, as:

$$P = -\frac{d\,H}{d\,t}$$

or, more general:

$$= \frac{m_0}{2\,f}\sqrt{\frac{L}{C}}\,\epsilon^{-2\,m_0 t}\,\left\{(\epsilon^{+2f\lambda_2} - \epsilon^{+2f\lambda_1})\,(A^2+B^2) - (\epsilon^{-2f\lambda_2} - \epsilon^{-2f\lambda_1})\right.$$
$$\left.(C^2+D^2)\right\} \qquad (129)$$
$$= m_0\,l\sqrt{\frac{L}{C}}\,\epsilon^{-2\,m_0 t}\,\{A^2+B^2+C^2+D^2\}$$

The power dissipated in the resistance: $r'\,d\,\lambda = \frac{r\,d\,\lambda}{\sqrt{L\,C}}$ and in the conductance: $g'\,d\,\lambda = \frac{g}{\sqrt{L\,C}}\,d\,\lambda$ of a conductor element $d\,\lambda$, and so the total power dissipated in the circuit element $d\,\lambda$ is, in the same manner:

$$\frac{d\,p_1}{d\,\lambda} = \frac{d\,p'}{d\,\lambda} + \frac{d\,p''}{d\,\lambda} = 4\,w\left(\frac{d\,\eta_0}{d\,\lambda} + \frac{d\,\eta'}{d\,\lambda}\right) - 4\,m\left(\frac{d\,\eta''}{d\,\lambda} + \frac{d\,\eta'''}{d\,\lambda}\right) \qquad (130)$$

where, as before:

$$w = \tfrac{1}{2}\left(\frac{r}{L}+\frac{g}{C}\right)$$

$$m = \tfrac{1}{2}\left(\frac{r}{L}-\frac{g}{C}\right)$$

and, integrated over a complete period:

$$\frac{d P_1}{d \lambda} = 4\, w \frac{d\, \eta_0}{d \lambda} - 4\, m \frac{d\, \eta''}{d \lambda} \tag{131}$$

the power dissipated in the circuit contains a constant term.

$4\, w \dfrac{d\, \eta_0}{d \lambda}$, and a term which is a periodic function of the distance λ:

$4\, m \dfrac{d\, \eta''}{d \lambda}$, of double frequency.

Averaged over a half wave of the circuit, or a multiple thereof, the second term eliminates, and it is:

$$\frac{d P_1^0}{d \lambda} = 4\, w \frac{d\, \eta_0}{d \lambda}$$

thus, the power dissipated in a section $l = \lambda_2 - \lambda_1$ of the circuit, is by integrating between limits λ_1 and λ_2:

$$P_1^0 = \frac{w_0}{2f}\sqrt{\frac{L}{C}}\, \varepsilon^{-2 m_0 t} \left\{ \left(\varepsilon^{+2f\lambda_2} - \varepsilon^{+2f\lambda_1}\right)\left(A^2+B^2\right) + \left(\varepsilon^{-2f\lambda_2} - \varepsilon^{-2f\lambda_1}\right) \left(C^2+D^2\right) \right\} \tag{132}$$

$$= w \sqrt{\frac{L}{C}}\, \varepsilon^{-2 m_0 t} \left\{ A^2+B^2+C^2+D^2 \right\}$$

Denoting therefore:

$$M^2 = \left(A^2+B^2+C^2+D^2\right)\sqrt{\frac{L}{C}} \tag{133}$$

it is:

Energy stored in the electric field of the circuit section of length l:

$$H = \tfrac{1}{2}\, l\, M^2\, \varepsilon^{-2 m_0 t} \tag{134}$$

Power supplied to the conductor by the decay of the electric field of the circuit:

$$P = m_0\, l\, M^2\, \varepsilon^{-2 m_0 t} \tag{135}$$

Power dissipated in the circuit section l, by its effective resistance and conductance:

$$P_1^0 = w\, l\, M^2\, \varepsilon^{-2 m_0 t} \tag{136}$$

Power transferred from the circuit section l, to the rest of circuit:

$$P_0 = f\, l\, M^2\, \varepsilon^{-2 m_0 t} \tag{137}$$

That is:

w/m_0 = ratio of power dissipated in the section, to that supplied to the section by the stored energy of its electric field.

f/m_0 = fraction of power supplied to the section by its electric field, which is transferred from the section to adjoining sections (or, if $f < 0$, received from them).

f/w = ratio of power transferred to other sections, to power dissipated in the section.

$m_0 \div w \div f$ is the ratio of the power supplied to the section by its electric field, dissipated in the section, and transferred from the section to adjoining sections.

These relations obviously are approximate only, and applicable to the case, where the wave length is short.

VIII. REFLECTION AND REFRACTION AT TRANSITION POINT.

23. The general equation of the current and voltage in a section of a complex circuit is given by equations (109).

At a transition point λ_1 between section 1 and section 2, the constants change by equation (99).

Choosing now the transition point as zero point of λ, so that $\lambda < 0$ is section 1, $\lambda > 0$ is section 2, equations (99) assume the form:

$$\left.\begin{aligned} A_2 &= a_1 A_1 + b_1 C_1 \\ B_2 &= a_1 B_1 - b_1 D_1 \\ C_2 &= a_1 C_1 + b_1 A_1 \\ D_2 &= a_1 D_1 - b_1 B_1 \end{aligned}\right\} \tag{138}$$

and herefrom follows:

$$\left.\begin{aligned} c_2 (A_2^2 - C_2^2) &= c_1 (A_1^2 - C_1^2) \\ c_2 (B_2^2 - D_2^2) &= c_1 (B_1^2 - D_1^2) \end{aligned}\right\} \quad (139)$$

If now a wave in section 1, A, B, travels towards transition point $\lambda = 0$, at this point, a part is reflected, giving rise to the reflected wave C, D, in section 1, while a part is transmitted and appears as main wave, A, B, in section 2. The wave C, D, in section 2 would not exist, as it would be a wave coming towards $\lambda = 0$, from section 2, and not a part of the wave coming from section 1. In other words, we can consider the circuit as comprising two waves moving in opposite directions:

1. A main wave $A_1\, B_1$, giving a transmitted wave $A_2\, B_2$ and reflected wave $C_1\, D_1$.
2. A main wave $C_2\, D_2$, giving a transmitted wave $C_1'\, D_1'$ and reflected wave $A_2'\, B_2'$.

The waves moving towards the transition point are single main waves, $A_1\, B_1$ and $C_2\, D_2$, and

The waves moving away from the transition point are combinations of waves reflected in the section, and waves transmitted from the other section.

Considering first the main wave moving towards rising λ: in this, $C_2 = 0 = D_2$, hence, by (138):

$$\left.\begin{aligned} A_2 &= \frac{2\, c_1}{c_1 + c_2} A_1 \\ B_2 &= \frac{2\, c_1}{c_1 + c_2} B_1 \end{aligned}\right\} \quad (140)$$

Herefrom it follows:

The *main wave* in section 1:

$$\left.\begin{aligned} i_1 &= \varepsilon^{-m_0 t}\, \varepsilon^{+f_1 \lambda} \{A_1 \cos q\, (\lambda - t) + B_1 \sin q\, (\lambda - t)\} \\ e_1 &= c_1\, \varepsilon^{-m_0 t}\, \varepsilon^{+f_1 \lambda} \{A_1 \cos q\, (\lambda - t) + B_1 \sin q\, (\lambda - t)\} \end{aligned}\right\} \quad (141)$$

when reaching a transition point $\lambda = 0$, resolves into the *reflected wave*, turned back on section 1:

$$\left.\begin{aligned} i_1' &= -\frac{c_2 - c_1}{c_2 + c_1}\epsilon^{-m_0 t}\epsilon^{-f_1\lambda}\{A_1 \cos q(\lambda + t) - B_1 \sin q(\lambda + t)\} \\ e_1' &= +\frac{c_2 - c_1}{c_2 + c_1}\epsilon^{-m_0 t}\epsilon^{-f_1\lambda}\{A_1 \cos q(\lambda + t) - B_1 \sin q(\lambda + t)\} \end{aligned}\right\} \qquad (142)$$

and the *transmitted wave*, which by passing over the transition point, enters section 2:

$$\left.\begin{aligned} i_2 &= \frac{2\,c_1}{c_1 + c_2}\epsilon^{-m_0 t}\epsilon^{+f_2\lambda}\{A_1 \cos q\,(\lambda - t) + B_1 \sin q\,(\lambda - t)\} \\ e_2 &= c_2\frac{2\,c_1}{c_1 + c_2}\epsilon^{-m_0 t}\epsilon^{+f_2\lambda}\{A_1 \cos q(\lambda - t) + B_1 \sin q(\lambda - t)\} \end{aligned}\right\} \qquad (143)$$

the reflection angle, $\tan(i_1') = -\frac{B_1}{A_1}$, is supplementary to the impact angle: $\tan(i_1) = +\frac{B_1}{A_1}$, and transmission angle: $\tan(i_2) = +\frac{B_1}{A_1}$.

Reversing the sign of λ in the equation (142) of the reflected wave, that is, counting the distance for the reflected wave also in the direction of its propagation, and so in opposite direction to the main wave and the transmitted wave, equation (142) becomes:

$$\left.\begin{aligned} i_1'' &= +\frac{c_2 - c_1}{c_2 + c_1}\epsilon^{-m_0 t}\epsilon^{+f_1\lambda'}\{A_1 \cos q\,(\lambda' - t) + B_1 \sin q \\ &\qquad (\lambda' - t)\} \\ e_1'' &= +c_1\frac{c_2 - c_1}{c_2 + c_1}\epsilon^{-m_0 t}\epsilon^{+f_1\lambda'}\{A_1 \cos q\,(\lambda' - t) + B_1 \sin q \\ &\qquad (\lambda' - t)\} \end{aligned}\right\} \qquad (144)$$

and it is then:

$$i_2 + i_1'' = i_1$$

or:

$$\left.\begin{aligned} i_1 + i_1' &= i_2 \\ \frac{c_1}{c_2} e_2 + e_1'' &= e_1 \\ e_1 + e_1'' &= e_2 \end{aligned}\right\} \quad (145)$$

33. That is:

1. In a single electric wave, current and electromotive force are in phase with each other. Phase displacements between current and electromotive force can occur only in resultant waves, that is, in the combination of the main and the reflected wave, and then are a function of the distance λ, as the two waves would travel in opposite directions.

2. When reaching a transition point, a wave splits up into a reflected wave and a transmitted wave, the former returning, in opposite direction, over the same section, the latter entering the adjoining section of the circuit.

3. Reflection and transmission occur without change of the phase angle. That is, the phase of the current, and of the voltage, in the reflected wave and in the transmitted wave, at the transition point is the same as the phase of the main wave or incoming wave. Reflection and transmission with a change of phase angle can occur only by the combination of two waves traveling in opposite direction, over a circuit, that is, in a resultant wave, but not in a single wave.

4. The sum of the transmitted and the reflected current equals the main current, when considering these currents in their respective direction of propagation.

The sum of the voltage of main wave and of reflected wave, equals the voltage of the transmitted wave.

The sum of the voltage of the reflected wave, and of the voltage of the transmitted wave, reduced to the first section by the ratio of voltage transformation $\frac{c_2}{c_1}$, equals the voltage of the main wave.

5. At the transition point, so a voltage transformation occurs,

by the factor $\frac{c_2}{c_1} = \sqrt{\frac{L_2}{C_2} \frac{C_1}{L_1}}$, that is, the transmitted wave of voltage equals the difference between main wave and reflected wave, multiplied by the transformation ratio $\frac{c_2}{c_1}$; $e_2 = \frac{c_1}{c_2}(e_1 - e_1'')$. As a result thereof, in passing from one section of a circuit to another section, the voltage of the wave may decrease or may increase. If $\frac{c_2}{c_1} > 1$, that is, when passing from a section of low inductance and high capacity, into a section of high inductance and low capacity, as from a transmission line into a transformer or a reactive coil, the voltage of the wave is increased; if $\frac{c_2}{c_1} < 1$, that is, when passing from a section of high inductance and low capacity, into a section of low inductance and high capacity, as from a transformer to a transmission line, the voltage of the wave is decreased.

This explains the frequent increase to destruction voltages, when entering a station from the transmission line or cable, of an impulse or a wave, which in the transmission line is of relatively harmless voltage.

34. The same equations also apply for a wave passing the transition point in opposite direction, and combining both waves gives the total expressions of current and voltage on the two sides of the transition point.

In the neighborhood of the transition point, that is, for values λ, which are sufficiently small, so that $\varepsilon^{+l\lambda}$ and $\varepsilon^{-l\lambda}$ can be dropped, this gives the equations:

$$\begin{aligned} i_1 = \varepsilon^{-m_0 t} \Big[\{A_1 \cos q(\lambda - t) + B_1 \sin q(\lambda - t)\} - \frac{c_2 - c_1}{c_1 + c_2} \{A_1 \cos q \\ (\lambda + t) - B_1 \sin q(\lambda + t)\} - \frac{2\, c_2}{c_1 + c_2} \{C_2 \cos q(\lambda + t) + D_2 \\ \sin q(\lambda + t)\}\Big] \end{aligned}$$

$$\begin{aligned} e_1 = c_1 \varepsilon^{-m_0 t} \Big[\{A_1 \cos q(\lambda - t) + B_1 \sin q(\lambda - t)\} + \frac{c_2 - c_1}{c_2 + c_1} \{A_1 \cos q \\ (\lambda + t) - B_1 \sin q(\lambda + t)\} + \frac{2\, c_2}{c_1 + c_2} \{C_2 \cos q(\lambda + t) + D_2 \\ \sin q(\lambda + t)\}\Big] \end{aligned} \qquad (146)$$

$$\begin{aligned} i_2 = & - \varepsilon^{-m_0 t} \left[\{ C_2 \cos q (\lambda + t) + D_2 \sin q (\lambda + t) \} - \frac{c_1 - c_2}{c_1 + c_2} \{ C_2 \cos q \right. \\ & (\lambda - t) - D_2 \sin q (\lambda - t) \} - \frac{2\, c_1}{c_1 + c_2} \{ A_1 \cos q (\lambda - t) + \\ & \left. B_1 \sin q (\lambda - t) \} \right] \end{aligned}$$

$$\begin{aligned} e_2 = & \; c_2 \varepsilon^{-m_0 t} \left[\{ C_2 \cos q (\lambda + t) + D_2 \sin q (\lambda + t) \} + \frac{c_1 - c_2}{c_1 + c_2} \{ C_2 \cos q \right. \\ & (\lambda - t) - D_2 \sin q (\lambda - t) \} + \frac{2\, c_1}{c_1 + c_2} \{ A_1 \cos q (\lambda - t) + \\ & \left. B_1 \sin q (\lambda - t) \} \right] \end{aligned}$$

In these equations, the first term is the main wave, the second term its reflected wave, and the third term the wave transmitted from the adjoining section over the transition point.

Expanding and rearranging equations (146) gives as the distance phase angles of the waves:

$$\left. \begin{aligned} \tan i_1 &= \frac{c_2 \{ (B_1 - D_2) \cos qt + (A_1 + C_2) \sin qt \}}{(c_1 A_1 - c_2 C_2) \cos qt - (c_1 B_1 + c_2 D_2) \sin qt} \\ \tan i_2 &= \frac{c_1 \{ (B_1 - D_2) \cos qt + (A_1 + C_2) \sin qt \}}{(c_1 A_1 - c_2 C_2) \cos qt - (c_1 B_1 + c_2 D_2) \sin qt} \end{aligned} \right\} \qquad (147)$$

hence:

$$\frac{\tan i_2}{\tan i_1} = \frac{c_1}{c_2} = \sqrt{\frac{L_1 C_2}{L_2 C_1}} \qquad (148)$$

$$\left. \begin{aligned} \tan e_1 &= \frac{(c_1 B_1 + c_2 D_2) \cos qt + (c_1 A_1 - c_2 C_2) \sin qt}{c_2 \{ (A_1 + C_2) \cos qt - (B_1 - D_2) \sin qt \}} \\ \tan e_2 &= \frac{(c_1 B_1 + c_2 D_2) \cos qt + (c_1 A_1 - c_2 C_2) \sin qt}{c_1 \{ (A_1 + C_2) \cos qt - c_1 (B_1 - D_2) \sin qt \}} \end{aligned} \right\} \qquad (149)$$

hence:

$$\frac{\tan e_2}{\tan e_1} = \frac{c_2}{c_1} = \sqrt{\frac{L_2 C_1}{L_1 C_2}} \qquad (150)$$

That is, at a transition point the distance phase angle of the wave changes, so that the ratio of the tangent functions of the phase angles is constant, and the ratio of the tangent functions of the phase angles of the voltages is proportional, of the currents inversely proportional to the ratio of the circuit constants $c = \sqrt{\frac{L}{C}}$.

That is, transition of an electric wave or impulse, from one section of a circuit to another, takes place at a constant ratio of the tangent functions of the phase angle, which ratio is a constant of the circuit sections, between which the transition occurs.

This law is analogous to the law of refraction in optics, except that in the electric wave it is the ratio of the tangent functions, while in optics it is the ratio of the sine functions, which is constant and a characteristic of the media, between which the transition occurs.

This law so may be called the

Law of refraction of a wave at the boundary between two circuits, or at a transition point.

The law of refraction of an electric wave at the boundary between two media, that is, at a transition point between two circuit sections, is given by the constancy of the ratio of the tangent functions of the incoming and reflected wave.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29–July 2, 1908.

Copyright 1908. By A.I.E.E.
(*Subject to final revision for the Transactions.*)

NOTES ON THE ELECTRIC HEATING PLANT OF THE BILTMORE ESTATE

BY CHARLES E. WADDELL

Under the conditions of modern life electricity is an indispensable adjunct to the successful conduct of an establishment the size of Biltmore House; in this residence, besides the power, lighting and signal service, it is now also used for heating.

For the last two years both the hot water system and the laundry have been operated by electricity. Before entering upon a detailed description of the systems, the reasons for the substitution of electricity for fuel will be briefly stated. Under former conditions, to supply the laundry with steam and to maintain a supply of hot water, it was necessary to keep both a hot water heater and a high pressure boiler constantly fired. To operate the plant required the services of three attendants. At certain hours of every day a portion of the attendants' time was required by other duties; but in the summer months and when the house was unoccupied, their entire time was virtually bestowed upon this very small duty. Anthracite coal, costing approximately $11 per long ton, was used. The difficulty in maintaining an adequate supply, together with the noise and dirt incidental to unloading, and the cost of the removal of the ashes, rendered its use undesirable and very expensive.

The majority of southern hydroelectric corporations furnish power under certain imposed conditions as to peak, load-factor and the like, at approximately 8.5 miles per kilowatt-hour. A study of all the conditions and a review of these facts indicated that economy would result from an abandonment of fuel and the introduction of electric heat.

The plant as it stands has a capacity of 167 kw. and it has thus far fulfilled all expectations as to economy and reliability.

Hot Water System. The hot water system is that common to all large buildings. It consists of a loop system of piping, leading from storage tanks, and so laid out that gravity maintains a constant circulation. As a consequence, the temperature is to all practical purposes uniform throughout the house, and on no line is it necessary to withdraw a quantity of cold water before the hot comes. The stand-by losses are of course excessive, but the comfort more than compensates for the additional cost. Two storage tanks are employed, each with a capacity of 500 gal. Into the top of one of these cold water from the main enters; from the side and bottom a loop of ,three-inch pipe is taken out and carried to the heaters which are located some twenty-five feet lower. The heaters are the lowest point of the system.

Heat was formerly supplied by a type of heater, which closely resembled a self-contained vertical tubular boiler. To maintain an adequate supply of water at a temperature of 200° fahr. required a fuel consumption of ten pounds of anthracite coal per hour. Tests of long duration showed this to vary but little.

The electric heater is a cylindrical steel tank, three feet in diameter by five long, containing twenty flues arranged in two concentric circles, and the whole closely resembling in appearance a miniature horizontal tubular boiler. Each of the twenty flues contains a heating element of 5 kw. capacity; consequently the total capacity of the heater is 100 kw. The connecting terminals are brought out at one end of the tubes; at the other end a nut holds the elements in place. The withdrawal of the element is accomplished by simply removing the nut.

The electric heater is installed beside the coal heater and the two are provided with valves so that either or both may be used as occasion demands.

Electricity is supplied in the form of a three-phase, 60-cycle, alternating current at a potential of 230 volts. A switchboard panel is installed immediately in front of the heater and the elements are grouped thereon in three banks, each bank connected to phase, a feature of great value in balancing the load on the transformers. The power-factor of the elements is unity. This was determined by observing the current consumption first on the direct-current circuit and then on the alternating, the amperage in each case being the same.

The form of the hot water heater and the uniform rate of fuel consumption led to the conclusion that its efficiency was considerably higher than the ordinary steam boiler, and probably approximated 65 per cent. Assuming the coal to have a heat value of 14,000 B.t.u., the effective value would be 9100 B.t.u.; and since 1 kw-hr. is equivalent to 3412 B.t.u., it appeared that an input of 26.6 kw. would be an equivalent.

The approximation was so close that when the electric heater was placed in service, 30 kw., were applied; and with the exception of a few hours in the late evenings when 5 or 10 kw. more are necessary, or the early mornings when not so many are needed, this input has been varied but little.

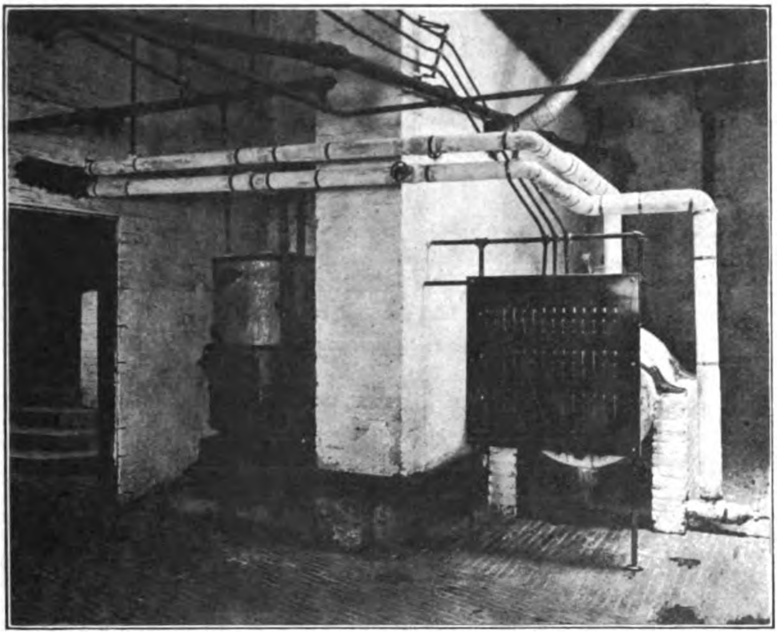


FIG. 1—Fuel and electric hot water heaters

The energy input in any apparatus is divided into useful work and heat losses; in heating apparatus since the entire work is the production of heat, where the elements are totally immersed, the efficiency theoretically should be 100 per cent.; this is modified to some extent by the heat absorbed by the material of which the element is made.

In order to determine the actual working efficiency of the above heater, its piping was disconnected from the system, cold water was introduced, and the valve so adjusted that with a fixed input of 40 kw. the water discharged was at constant temperature. The discharge was weighed, the input meter read at the start and conclusion of the test, and from these data the net efficiency found to be approximately 85 per cent. That is to say, 85 per cent. of the input becomes available and effective, in the hot water system; the other 15 per cent. is lost in

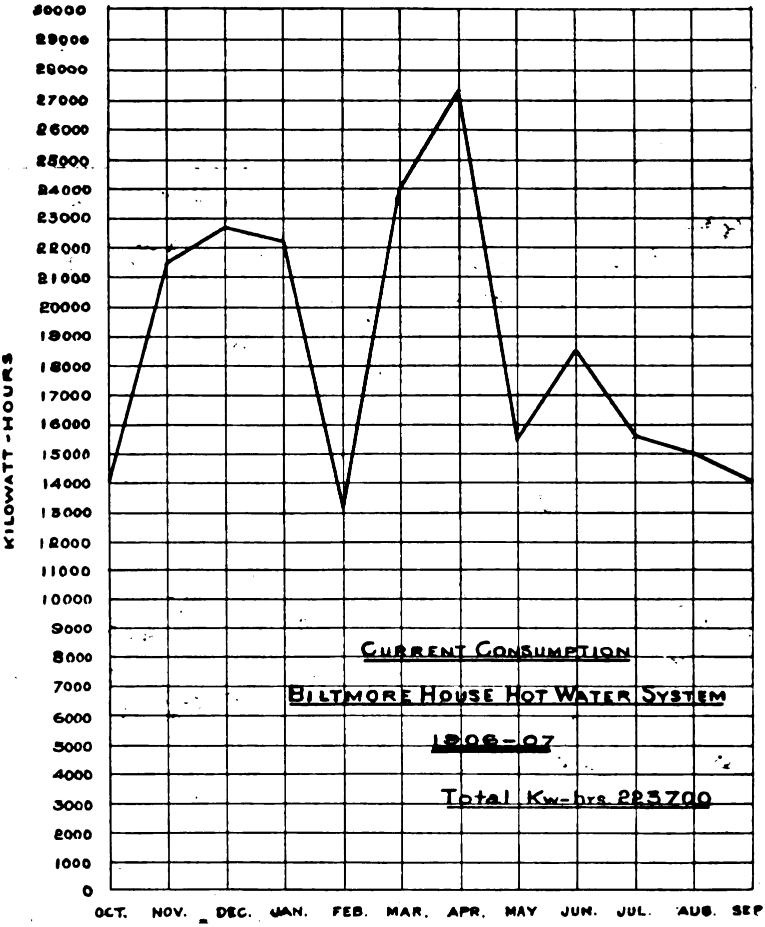


FIG. 2

radiation from the boiler shell, through the tubes, and from the attachments and piping. The author is of the opinion that the recorded efficiency is too low and may be considered as ultra conservative. Nevertheless it represents the efficiency of the plant under everday working conditions, and is not a test under artificial conditions, such as electric apparatus is often subjected to and which bear scant relation to working conditions.

The water at Biltmore contains a number of carbonates, causing boiler flues to form scale and incrustations rapidly and to an excessive degree; and with all steel piping which is subjected to a cycle of temperature change there is a continuous struggle to remove this coating. In the light of experience, although it would materially, increase the cost, the use of copper flues instead of the iron ones now employed seems a justifiable expense. With a flue that would not retain scale, the formation of scale on the shell would be in the nature of additional heat insulation and would be beneficial rather than otherwise.

Ordinarily the deterioration of electric heating elements appears to be rapid; 10,000 hours is seemingly the maximum guarantee to be had. In the case of an element employed in heating water, where the element is at all times submerged, the maximum attainable temperature difference is but 180° fahr. and the deterioration is nothing like so rapid as in other classes of service.

Speaking in the dual capacity of purchaser and seller of power, the writer does not hesitate to say that electric heating for hot water service is the most satisfactory and profitable load to be had. Peak loads are the rare exception; close regulation is non-essential; and momentary interruptions to service are of no importance; and even in prolonged shut-downs the slow thermal change of the liquid is such that ample time to start the auxiliary fuel plant is afforded.

Fig. 2 is a chart showing the monthly current consumption for a year; 20,000 kw-hr. per month is considered normal. When less is recorded the consumption was purposely curtailed in order to keep the total current for the estate within the contract allowance.

The cost of the fuel heater, complete, installed, was about $350. The cost of the electric heater, complete, installed, and including switchboard, foundations, and pipe connections, was approximately $1200.

LAUNDRY EQUIPMENT

The electric equipment installed consists of:

1 Dry room heater, capacity approximately 16 kw.
1 Mangle, 48 in. by 16 in., capacity 8 kw.
4 4-iron stoves, each with a capacity of 2 kw., total 8 kw.
1 Steam generator, capacity 35 kw.
Total capacity 67 kw.

From the main switchboard current is conducted to the laundry by three 500,000 cir. mil cables which terminate in a three-wire cabinet, the capacity of the panel being 1000 amperes. All conductors are run in galvanized conduit, the most substantial construction is followed, the aim being to secure an installation comparing favorably with steam apparatus in simplicity and durability. All laundry apparatus works interchangeably on direct or alternating current.

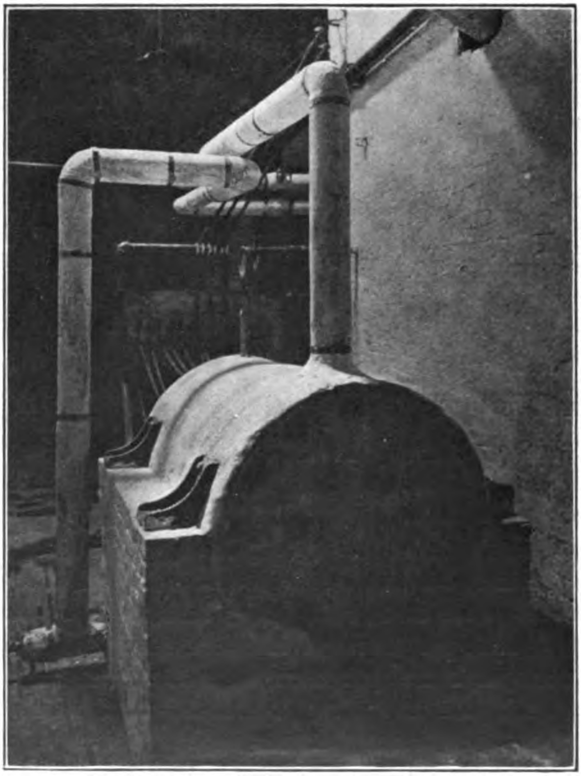


FIG. 3—Rear view of 100 kw. hot water heater

The dry room with a cubical contents of 640 feet is provided with three heating elements in the form of plates which are supported on porcelain insulators resting on the floor. Connections from the controlling switch box are made through asbestos covered wire and mechanical, in preference to soldered, joints are used where possible. The dryer is equipped with the ordinary form of vertical clothes racks travelling on rollers. To accelerate the process of drying an 18 in. galvanized iron flue leads from the top of the room to a nearby chimney. In laying out this apparatus it appeared feasible to supply only heat sufficient to maintain circulation; the theory being that rapid

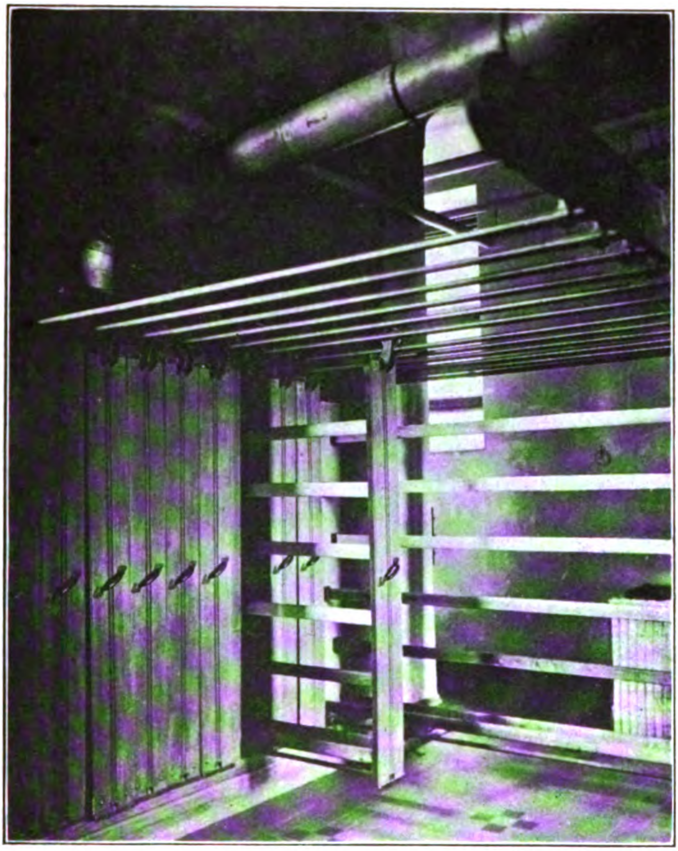


FIG. 4—Dry room, showing clothes racks and air flue

passage of warmed air would more or less mechanically exhaust the moisture.

In this connection it may be of interest to show how the equivalent heating capacity was determined. Originally the room was equipped with 108 sq. ft. of radiation in the form of 1 in. pipe. The steam pressure was kept at 60 lb. gauge; representing a temperature of 309° fahr. The temperature of the air in the dry room was usually 185° fahr., a difference of 124° fahr. Assuming that 1 in. wrought iron pipe radiates 2.9 B.t.u. per sq. ft. per degree difference of temperature; and since 1 kw-hr. is equivalent to 3412 B.t.u.; we have:

$$\frac{2.9\times124\times108}{3412}=11.4\text{ kw.}$$

Practically 12 kw.; a capacity on which all estimates were based. The discrepancy between the calculated and installed capacities is due to our use of certain elements on hand that would otherwise have been idle; and the greater capacity appears to facilitate the work.

The following is the average weekly performance, the dryer being used three days, and each day listed separately for comparison.

Monday, March 30, 1908. General household wash, such as shirts, underclothes, stockings, table linen, towels, sheets, etc.

Number of hours used	10.5
" " articles dried	339
Weight " " dry, lb	103
Average temperature	101° fahr.
Number of lb. water expelled	84
Kw-hr	124

lb. water expelled per kw-hr	0.68
lb. clothes dried " " "	0.83
Number of pieces " " "	2.73

Thursday, April 2, 1908. Used for drying 18 shirts only. Shirts had been starched.

Number of hours used	4
" " articles dried	18
Weight " " dry, lb	9
Average temperature	110° fahr.
Number of lb. water expelled	12
Kw-hr	68.4

The heater was turned on at 8 a.m. and in empty state reached working temperature in one hour. Clothes were put in 1.5 hours after current was turned on; the mere act of drying, therefore, required 33 kw-hr.

Friday, April 3, 1908. Second general wash.

Number of hours used	7.25
" " articles dried	276
Weight " " dry, lb	143
Average temperature	110° fahr.

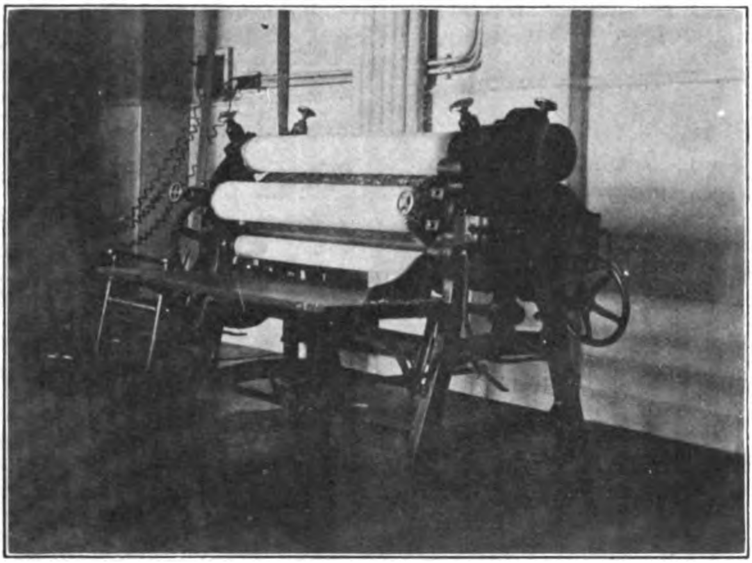


Fig. 5--Electrically heated mangle

Number of lb. water expelled	182
Kw-hr	125
lb. water expelled per kw-hr	1.45
lb. clothes dried " " "	1.14
Number of pieces " " "	2.20

Clothes ordinarily enter the dryer at a temperature of 83° fahr., having previously been raised to a high temperature in the process of boiling and washing.

The steam mangle formerly used was converted to electric service by providing the rotating drum with heating elements.

Connection with the circuit is effected by means of a 3-ring collector and carbon brushes. Three degrees of heat may be had, the maximum input is 8 kw. and the heating intensity is 475 watts per sq. ft. of surface. The performance of this machine is far more satisfactory than when used with steam; especially gratifying is the absence of leaky stuffing boxes.

The record of an average day's work is given below:

Current turned on mangle at 6.30 a.m.

Mangle started to work at 8.30 a.m., stopped at 2.30 p.m., off 45 min. for lunch; off 30 min. to cool; total hours current was on, 6.45.

Amperes, 45; volts, 118.

Two girls working. Articles mangled were: towels, table cloths, napkins, sheets, bed spreads, pillow cases.

Total weight articles in lb	221.
“ square feet mangled	12,256.
“ number of pieces	471
“ kw-hr	35.8

All pieces were passed through twice, and many pieces three times, this accounts for the large surface area. The articles were cotton and linen.

The cost of equipping this mangle, including freight, drayage and installation, was approximately $175.

The diversity in weights, shapes and uses of the sad irons in this laundry led to the selection of electric stoves in preference to electric irons. Experience has taught that such claims were given undue consideration, and I am now of the opinion that an equipment of electric irons weighing from 7 to 12 lb. would be preferable. For heating very special shaped irons, used on laces, etc., one stove might prove necessary. A consideration entirely apart from the merits of the irons has led to their partial abandonment, and that is that with the advent of the electric apparatus the temperature of the laundry was lowered to a degree where the ironed clothes would not "air" properly, and it was found necessary to keep the coal stove going to overcome this obstacle. It appears that where clothing is at once stored, and not again immediately used, that this "airing" is essential to their preservation. With the coal stove working the use of the electric stoves was in the nature of a waste.

Below is given the record of a day's ironing using the electric stoves:

Two girls worked six hours each.

219 pieces ironed; articles were stockings, handkerchiefs, towels, napkins, pillow cases, petticoats, skirts.

Gross weight, damp, lb	63
Net " dry, lb	41
Kw-hr	24

It required 40 minutes to bring stoves and irons to working temperature. An iron heats in 8 minutes after being returned to the stove, and will hold sufficient heat to iron from 4 to 7 minutes, depending on the dampness of the article and the material. To properly iron a handkerchief requires 7 minutes, a bath towel 4 minutes.

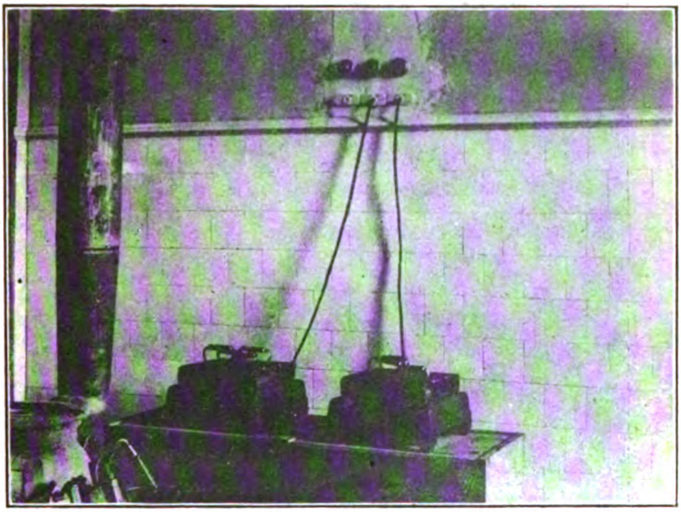


FIG. 6—Electric stoves for sad irons

The foregoing data are submitted simply as an illustration of actual performance, and represent average results; they are given in detail that others working along the same line or being confronted with new problems may glean some help from our experience. When the plant was begun we quickly realized the dearth of available data; and I believe that if all experimenters will publish the results of their investigations, facts will be gathered from the mass of testimony which will result in improved and more efficient apparatus.

Allusion has been made to the use of electric irons versus electric stoves; in connection with the former attention is called to the matter of cords and attachments. These are the weak points in this class of apparatus. The cords get damp and short-circuit, the terminals break loose, and the insulation frays off.

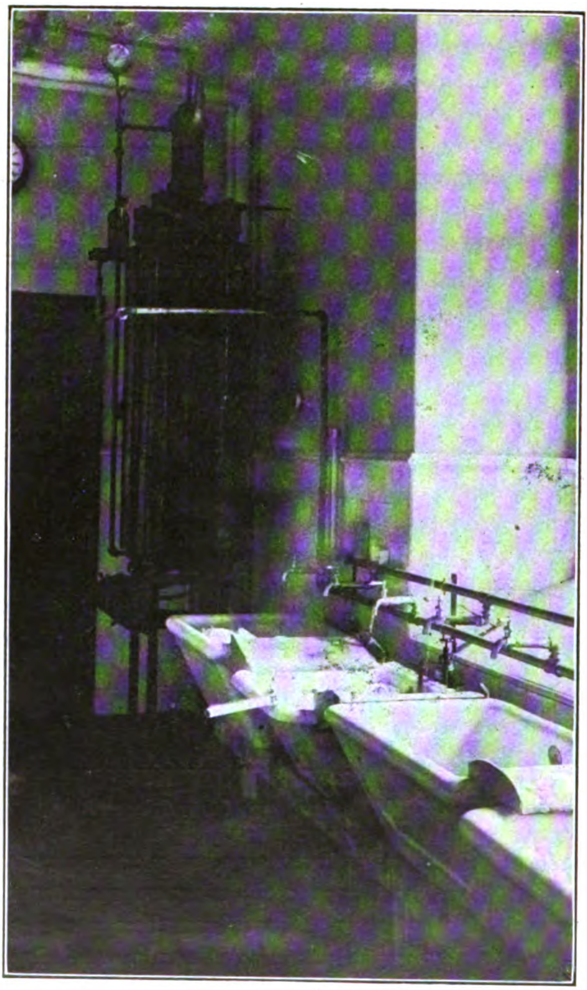


FIG. 7—Steam generator and laundry tubs

For small irons and light service the existing practice is fairly good, but in heavy work, to insure success, a more substantial equipment must be designed.

By far the most interesting piece of electrical apparatus at

Biltmore is the steam generator. With the abolition of steam service some method of boiling the clothes had to be provided. Of the several suggested and tried forms, the one in use seems best suited to the requirements. In the winter when steam heat is on the house, it is in the direction of economy to use steam from the mains. For nine months of the year heat must be secured elsewhere. Boiling the clothes is an essential process. To retain intact the steam apparatus was an obvious desideratum; to provide supplementary electric apparatus introduced complications; and a compromise was effected by generating steam with electricity, piping the generator into the steam mains, a series of valves rendering the two sources of heat interchangeable. The steam generator consists of a group of five 3-in. vertical pipes. Around the pipes the heating elements are placed. The pipes are interconnected at both top and bottom; the top is provided with a steam dome; and the whole is equipped with water column, steam gauge, pop valve and inlet water regulator. The function of the regulator is to keep the water level in the

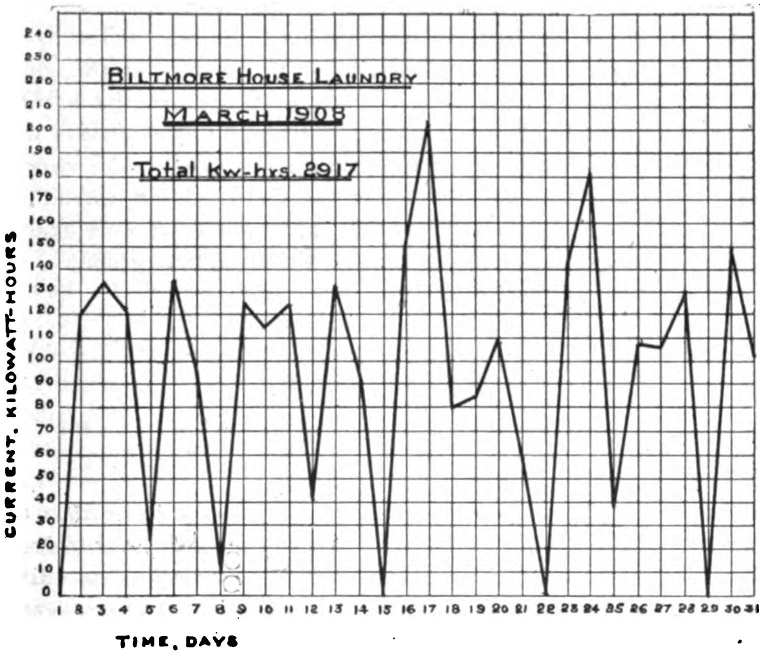


FIG. 8

boiler constant. Feed water is taken from the hot water mains. At the base, and integral with the frame, are five switches, each controlling a 7 kw. element.

Steam at practically zero pressure is conducted to five tubs and there discharged through perforated pipes located in the bottoms. The tubs are made of porcelain and contain about 2 cu. ft. each.

When new the generator was tested to determine its evaporative efficiency; this was found to be between 95 and 100 per cent. The appliances at hand were not adapted to precise work, but the result is not very far wrong in my opinion. The test was made by bringing the contents of the boiler to the boiling point, marking the height of the water on the gauge glass, evaporating a given weight and ceasing when the water in the boiler was level with the starting point. The meters were read at start and finish, and the input determined. The varying barometer and the inaccuracies of the thermometers introduced error, and it is by no means certain that the meters were exactly right, although they were new and of the highest grade.

In service the performance is as follows:

92 lb. water in tub.
7 lb. linen " "
To raise to boiling point requires 10 kw-hr.
Clothes are boiled 20 min. and current consumed is 4 kw-hr.
Total kw-hr. per batch........................14

Digressing from the subject, it seems to the author that this form of steam generator is admirably adapted to the service of train heating, where steam and electric locomotives are alternately employed. Worked in connection with a return system of piping, water storage only sufficient to supply leakage would be necessary. The generator being located on the locomotive the increase in weight on the drivers would be an advantage. The low cost, and the simplicity of the apparatus together with the fact that it would fit existing equipment should, I think, render an experiment worth while.

Plate Warmer—In addition to the two large classes of service that have been described, there is installed in the butler's pantry an electric plate warmer. This piece of apparatus is in the form of two shelves, each 24.5 in. by 43 in. and each with a rated consumption of 840 watts; an equivalent heating effect of 0.8 watts per square inch of surface. Each shelf is provided with its own switch, the ordinary double-pole indicating snap switch is employed for control, the wiring is of the fire-proof form of insulation, and the current supply is taken from a nearby lighting main. The lighting system being designed for operation on either the alternating bus-bars or the direct-current storage battery bus-bars, it follows that, like the laundry, the plate warmer works interchangeably on the two classes of service.

At the time of purchase this type of heating apparatus sold for approximately $6 per square foot.

Conclusion—As was aptly pointed out in an editorial of a representative technical paper not long since, electric heating has suffered from the fact that its economic possibilities have usually been considered from its thermal unit value; and the lesson to be drawn from the Biltmore installation is that a careful analysis of all the conditions may disclose the fact that while theoretically a disparity exists, nevertheless economy may accrue due to the better operating conditions.

Enthusiastic advocates of electric heating are to-day making broad claims which in a measure mislead the uninitiated; this in the author's humble opinion should be discouraged. The prices at which electric power is generally sold and the state of the heating art do not as yet admit a wholesale and unreserved usurpation of the heating field; and it is a question whether this state ever will be reached. One thing, however, is certain, and that is that Utopian dreams and unsubstantiated claims are going to do much harm and no good; and all projected heating installations of any magnitude should be accorded careful attention and considered in the light of an engineering undertaking, not merely as a matter of domestic or commercial installation.

We have found that the standard forms of enclosed fuses when continuously worked at or near their rated capacity on heating apparatus rapidly deteriorate, failing without apparent cause. For this fact I have no explanation to offer.

Experience leads to the conclusion that for heavy heating work a number of auxiliary appliances accepted as standards in lighting work will have to be either remodeled or abandoned. The temperature at which heating elements work renders the use of solder undesirable; in a number of instances that have come under our observation the terminals have melted off. The use of fire-proof or asbestos covered wire is to be preferred to rubber, even in conduit installations.

Where cords are required it would appear better construction to use flexible armored cable. For stationary apparatus the switching devices should as far as possible form an integral part of the apparatus; and where necessary to separate the two, connection between them should be made through conduit, and both switch and heating element be arranged to mechanically unite with the conduit. In the majority of places where electric heating apparatus is employed water or steam is present, and for this reason the switching devices should be accorded special attention. The open knife switch is altogether unsuitable; the enclosed knife switch some, but not much, better; and the oil switch entirely out of place. A little mechanical ingenuity bestowed upon these details would effect a decided advance in the art and would eliminate one source of trouble.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29–July 2, 1908

Copyright 1908. By A.I.E.E.
(*Subject to final revision for the Transactions.*)

RELATION OF THE MANUFACTURING COMPANY TO THE TECHNICAL GRADUATE

BY DAVID B. RUSHMORE

Conditions in the commercial world necessitate an increasing consideration being given to the perfecting of organization and to raising the standard of individuals composing the same. The present may be said to be distinctly an age of organization, and in the competition which naturally exists, the relative efficiency attained by different organizations has much to do with their survival in the competitive struggle of modern times. Much thought is now being expended on this question and a great deal of good is resulting from the study being made of it. A whole can reach its best condition only when all of the parts which compose it are of the first class. This means that the individuals composing an organization must be of the best quality both as regards natural and acquired ability. There is an increasing demand for highly trained men, and there is considerable discussion as to what that training should be. A man who has concentrated his energies for four years on a special line of work is naturally more efficient in that line than would be possible otherwise, and consequently the properly trained college man is more efficient than the man without a college education. The ranks of industrial manufacturing concerns are, without question, becoming more largely filled with college graduates and therefore the importance of the technical graduate is increasing. There will always be men of unusual natural ability who will succeed without a college education, but such individuals undoubtedly would have been able to accomplish more if they could have had the advantages of concentrated training correctly applied for a number of consecutive years.

Manufacturing companies must now to a large extent train their own men. These men must have a thorough acquaintance with the organization, must know the apparatus manufactured by it, and must be more or less familiar with the general business conditions and with the individuals handling that business. In a large electrical manufacturing company the ability to handle business in almost any department is to some degree dependent upon the familiarity of the individual with the apparatus concerned, as commercial, legal, and engineering questions are almost always involved together.

A manufacturing company naturally desires a considerable variety of men. There is a large amount of routine business to be transacted, and there is also a large amount of work calling for originality, initiative, and invention, which demands a different type. Men may remain in the shop organization, enter the general commercial department, enter the drafting room or engineering force, work out into the district offices in their engineering or commercial lines, may go with operating concerns to take charge of power plants and transmission systems, or they may branch out into the very wide variety of allied industries which use electrical apparatus and where trained electrical men are required. A considerable number find a useful field in consulting engineering, and a few get into positions where technical engineering ability is utilized in financial lines.

Some manufacturer has said that he could lose his whole factory equipment and still win out if allowed to keep his organization intact. Certainly organization is one of the most important factors in present industrial conditions. An organization means an aggregation of individuals each of whom is performing some more or less specialized function, but all working harmoniously together to a common end. Many men never learn that they are part of an organization, and persist in working as individuals and therefore lose much of their value to a large concern. To get the advantage of a large organization everybody's mind must be used for the whole, and the old military system of passing down all the orders from the top has largely disappeared. Coöperation is the watchword of modern industrial development. Conferences have become a standard way of arriving at decisions, but executive work must, of course, be single-headed. Concerns which make use of the idea of conferences and of using the minds of all of their members, while they may be a little slow in action, will always win in the end. The best organizations allow a free development of individuals, while restricting them to harmonious action. Initiative must be rewarded, suggestions freely accepted, and a healthful rivalry carefully watched and, if necessary, restricted. An individual entering a large concern becomes at once a member of an organization and must work as such. The entire line of thought and action is very different from a condition where he performs all functions himself. The ability to work as part of an organization can be largely acquired, and should be learned in a college course. It is usually one of the things which a man has to learn when he first gets out of college, and is sometimes rather a difficult lesson. Great importance is placed by manufacturing organizations also on personal habits, characteristics, etc., as well as mere technical knowledge.

The condition of a man after graduation depends to a considerable extent on the individual and somewhat on the college from which he comes. The recent graduate is necessarily somewhat theoretical in his point of view, and, while having a good foundation, has not the practical experience or the acquaintance with actual conditions which makes him of immediate value. There is a tendency at present to connect educational institutions with manufacturing establishments so closely that there shall be no sharp line of transition from one to the other. This looks somewhat ideal, but undoubtedly is a desirable tendency. A great deal in the present system is to be commended, and splendid men are being turned out. They are all willing to start in at the bottom, but very few are willing to stay there long. The ability to succeed in an industrial organization depends on a great many other things than mere technical knowledge, and the incidental developments at college bring out many faculties which are useful in later life. The participation in college athletics, debating societies, class functions, fraternities, publications, etc., develops the individual and assists him to follow such work after graduation. Cramming for examinations has even been commended on the score that this is what one has to do continually afterwards. Among the most importtant things which a man learns to do at college, especially in athletic contests, is to work with others; to do team work and not act as an individual, because a large part of the effectiveness of an organization depends on just such work. A college man naturally becomes something of an organizer, promoter, manager, and contestant, and gets a start in taking a broad view of conditions. It is dependent upon himself to develop this afterwards.

One of the most promising signs of the times is the close study and coöperation between manufacturers and colleges. College students frequently work in the shops during vacations, as do also college professors. In some colleges it is the intention to have the professors engage for a year or so in active practice, and then return to teaching for a few years. The whole trend is along a line which brings the college man in close touch with actual conditions. Much that the colleges are doing is excellent, and much can be said in favor of the ideas now being given consideration for future modifications. A few suggestions only are offered here.

The college graduate during his first year or two after graduation, is placed under new conditions, and requires some time to find himself. It has been suggested that he keep some relationship with his college during this time and that some systematic study in connection with this work be followed. Another suggestion is that college work should be from the beginning associated directly with the idea of costs. No real engineering is ever dis-associated from this feature. It usually takes a college man some time to learn that the best engineering is that which will serve the purpose, and cost the least. At least one college runs its shop in this way, and to instill this point of view into men while getting their education would be of much use afterwards. It is very easy to say what should be added to or taken from a college course, and it is only too easy for a man to make suggestions in this line, as is evidenced by the amount of material produced in the way of articles and discussions. Many men after graduation find a use for commercial law, for accounting, for a certain knowledge of business methods, and financial factors. It is suggested that some attention be paid to these in connection with engineering work. Professional men are very largely working on salaries, and a salaried position is always more or less of an insurance against the acquisition of wealth, so that for professional men no subject is of greater importance than the study of investments, and from a personal point of view this cannot start too soon.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29-July 2, 1908.

Copyright 1908. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

WATER POWER DEVELOPMENT IN THE NATIONAL FORESTS. A SUGGESTED GOVERNMENT POLICY

BY FRANK G. BAUM

In order to insure the supply of timber and to protect the water sheds and conserve the water of our mountain streams, the government some years ago adopted the policy of withdrawing large timber areas from entry by creating national forests. The preserves were to be operated by the forestry department for use and not for profit. Recently the government has given permits to companies proposing to make power developments on condition that the permits be revocable at the pleasure of the Secretary of the Interior, and that there be a conserving water royalty charge by the government on the power output of the plant.

Objections to temporary permits have been made by the power companies, as no one wishes to invest money to risk losing it through the whim of some official. Objections have also been made to the conservation charge, especially when it is based on the output of the plant. In this paper I shall try to arrive at what I believe to be a logical conclusion of a fair conservation charge.

The matter is of great importance because power development is advancing the progress of the country at an increasing rate, and a government policy retarding power development will retard this progress. Power development stands to-day at the same stage, so far as its influence on progress is concerned, as the construction of railroads did 20 or 40 years ago. The immense benefits to be derived from the development of cheap power and the resulting saving of our timber, oil, and coal resources should not be deferred by unfair government policy or indefinite assurances for the safety of the money invested.

The proper development of water powers would utilize resources now going to waste; the development of coal mines, on the other hand, means the consumption of resources now stored and available at any future time. Every hydroelectric horse power saves the consumption of about twelve tons of coal per year. Therefore the proper development of the water powers would conserve the country's coal resources to that extent. For example, 1,000,000 hydroelectric horse power transmitted to New York and its vicinity for manufacturing purposes would result in saving about 12,000,000 tons of coal per year. This coal could be reserved for domestic purposes. This is about 20,000 cars of 50 tons each per month, or 666 cars per day. The development and use of less than 25 per cent. of California's available water powers would stop all wood, oil, and coal burning for power purposes in that state. The same is true for nearly all the western states and a great many of the eastern and southern states.

In order to limit speculation, and at the same time to hasten water power development and save our wood, oil, and coal resources, I suggest that all rights-of-way and lands necessary for this development be given on condition that a certain proportion of the work be done each year and that a certain proportion of the development be completed within five years. This would put the man developing the water power on exactly the same basis as the miner and the farmer; it would prevent speculation and limit the operations to bona fide developments. No man or combination of men, no matter how wealthy and greedy, would then be able to monopolize the water power resources of this country. The statement that there is now danger of a water power monopoly in this country is utterly absurd to any one having a knowledge of the facts or the conditions under which water power developments must be made. The development of our water areas would help to conserve the coal areas, and would protect the national forests, where water power is developed, at no expense to the government.

It will be assumed that the object of the proposed conservation charge is not intended as a means to raise revenue for the government, but for the purpose of protecting, operating, and maintaining the forests, so that the greatest possible use may be made of them, not for this year or next, but with the idea of using the forests to produce a perpetual supply of food, timber, water, etc.

It follows as a natural conclusion that the different reserve sections must stand on their own merits; that is, the revenues in California, for example, should not be made so great that it would be impossible to use the revenue in the reserves in that section. In other words, it would be only fair that the revenue derived from a California reserve, say, should not be used to purchase, or maintain, a reserve in Maine.

It follows, further, that each reserve unit should stand on its own merits, and the money derived from any one reserve should, as far as possible, be used to maintain and promote the interests of that particular reserve unit. The people entitled to the products of the reserve, who should be given first consideration, would be those who settled in the country, many of them having *settled because of the resources in the reserves* adjacent to their place of settlement. Naturally, they should be entitled to first consideration in disposing of the products of the reserve. Those who settled in a particularly favorable location should not contribute to the reserves of a less favorable condition. This policy is, I believe, followed in giving grazing permits, and also in timber permits.

Coming now to a particular reserve. The reserve has resources mainly in feed, timber and water. The area of the feed and timber product of a reserve has no natural boundary. When we consider the water product, however, we find natural boundaries for each watershed, and logically to arrive at a fair and equitable basis for a conservation water charge we must consider each water shed by its natural boundary, and each watershed as a unit. The man wishing to make a power development should pay only a just proportion of the cost of maintaining the watershed and conserving the water. In a certain reserve, for example, there are two adjacent watersheds. The area of the two watersheds may be the same, and the water output also, but the cost of maintenance of the reserve lands in one shed be entirely different from that in the other; the value of the power resources in the two adjacent watersheds may be entirely different. Watershed A for instance, may, have an area of 100,000 acres, a water output of a certain number of average second-feet, and the power which can be economically developed, say, 5000 kw. Watershed B may have the same number of acres, but the economical power development may be 50,000 kw. On the basis of a fixed charge per kilowatt-year, as proposed, watershed B would give a revenue to the government ten times as great as that of watershed A. The revenue derived by the government on this basis from watershed B from the power resource, is much more than justifiable, considering the cost of protecting and maintaining same, and much more than can possibly be used in that particular watershed for any purpose benefiting the power privilege. It is only fair that the government's charge against the power privilege should be based *on what the government furnishes* to make the privilege operative. The cost of maintenance in the case A might be very much greater than in the case B, yet the revenue derived from B, on the basis of a fixed charge per unit of output, would be ten times as great as the revenue derived from A. Some parallel examples will illustrate the principle of the proposed method of fixing the charge.

The Reclamation Service, in charging for reclaiming lands, takes each district and applies all the cost equally to all the lands to be irrigated. If one watershed district offers opportunities for developing a project for $20 per acre, that is the charge made, although in the adjacent watershed, or district, the charge may be $40 per acre. That is, the principle is recognized that *the people settling in a particular area are entitled to all the natural resources belonging thereto.* No profit can be made from one area and applied to another. Similarly in power development, the man who develops in one watershed is entitled to all the natural advantages belonging to that area, and he should not be made to pay to help develop power on an adjacent watershed. None of the money contributed by him, because of his privilege, can be used rightly for any other purpose, except to benefit the watershed or privilege which he enjoys. The grazing and timber interests pay their just proportion of the cost to the government of the privileges enjoyed by them, and the power privilege should likewise pay its just proportion.

Suppose again that the government withdraws a given timber area in order to assure ties to several railroads that traverse it. What is a just charge for the ties? A charge on the gross or net revenue of the road, or a rate on the tonnage passing through the reserve would be absurd; the only fair charge would be on the value of the ties, calculated on the yearly expense of maintenance and the number of ties the reserve can produce annually. Why then should the water-power company pay a royalty on the basis of its power output? The grazing and timber interests are not taxed with the idea of producing a profit to the government, or that the grazing or timber interests of one section should support those of another, or that these interests should be taxed to support others. The miner is not charged a royalty by the government, but the government can rightly charge him for any direct benefit he may receive by reason of the reserves.

By all precedent, then, the principle is well established that the government should calculate the cost of what is furnished, and the conservation charge be made accordingly. This would establish the principle that the annual conservation charge should be based on the actual yearly cost to the government of the cost of conservation. The conservation charge would change from time to time, but there would be a definite basis for its determination.

Rights-of-way on lands occupied for reservoirs, pipe-lines, and power houses should be sold to the power company at a fair value, and these lands would not then enter into the determination of the conservation charge. Rights-of-way and lands necessary for the development should be the property of the company. These matters should be fixed independent of the conservation charge. We should not expect railroads to open up new country if their rights-of-way were revocable, or if they were charged on the basis of tonnage carried over the right-of-way.

Coming now to the analysis of a particular watershed and the privilege granted to the power company on it: the withdrawal and protection of the timber will generally affect the stream-flow, and a just charge can be made by the government for the protection given, as it directly benefits the privilege. The charge made for the protection of the timber and the stream-flow must naturally vary with the conditions, and must be calculated for each case, because other interests should also pay their just charge for the protection. The charge made for the reservoir privileges, rights-of-way, for canals, pipe-lines, and power-house sites should, however, be based on the value of the acreage occupied. Because a power development occupies a given piece of ground, makes it no more valuable to the seller (the government) than if it were to be occupied by a quartz mill, and the power man should pay no more than the miner or any other interest.

When the amount to be charged for the right-of-way, reservoir, and power-house sites is fixed, and the government has determined the amount to be expended yearly on the watershed, the amount to be charged for the power privilege can be easily fixed. It should make no difference in the charge whether 5000 kw. is obtained in power. or 50,000 kw. That is, as in the case of the farmer and the Reclamation Service, the man settling in the valley where conditions are favorable for low cost of irrigation should have the benefit of that condition. And the power man who uses his ingenuity and money to discover a better power development than another should also have the benefit of his enterprise. The government has not yet, and I hope never will, put a tax upon discovery, invention, and development.

Still further to show the reasonableness of a fixed total charge annually for a given watershed, we may merely cite the fact that if the charge is based on the kilowatt output, the man who puts in a cheap and wasteful system pays less than the man who puts in a more expensive and efficient system. Further, the man who sells his power for $20 per kilowatt year, pays double the percentage paid by the man who sells for $40 per kilowatt-year. And again, the man who takes this power to a market, say 100 to 300 miles away, must pay to the government for the losses and expense in doing so and pays more than the man who sells to the home market. The man who reaches out with his power is equalizing conditions, just as railroads equalize conditions by their transportation facilities, and should be encouraged and not taxed for doing so.

Coming to the case where the government owns part of the property necessary for the conservation and development, and part is owned by private parties, or the man making the development. For example, assume that the power company making the development owns a reservoir which controls the stream. Assume that this reservoir is the controling feature of the development, that without it the stream is virtually worthless. It may even be that the reservoir is all that is necessary, and the protection of the timber could have no effect on the development, and its removal would not affect the development in the least. Has the government a right to make a conservation charge when as a matter of fact the man is paying for his own conservation? In this case the government can only charge for rights-of-way and lands occupied, and no conservation charge can be justly made. If the government furnishes part of the conservation—this is usually the case—then a proper proportion of the basic rate of the conservation charge can be made.

This may be illustrated by taking the case of a man owning a timber area to which he had title before the establishment of a reserve. In order to make use of the timber it is necessary to obtain from the government land for a mill-site and right-of-way for a railroad from the timber to the mill-site. A proper charge for the land for the mill and right-of-way can only be made on the basis of the value of the lands occupied. A charge on the output of the mill would be entirely unjust; this will be admitted by all. Change the timber area to a reservoir, the mill-site to a power-house site, and the railroad to a pipe-line, and wherein lies the difference? The man purchased the reservoir before the reserve was established, to store water and develop power. In order to do this he must have the right-of-way for pipe-line and land for power-house site, and these must be granted him as in the case of the sawmill, on the basis of the land value, and not on a royalty of the power output. No royalty should be charged for giving the man the only opportunity there is to make use of his property. Any number of parallel cases could be cited to illustrate the principle. In creating a forest reserve the government cannot but recognize the rights of private individuals or companies who owned lands in the reserve previous to its establishment, and the government must allow owners the use of their property. Any other course would amount to confiscation.

The above suggested method of fixing the conservation charge is believed to be logical and treats the power interests as others. The amount to be charged yearly for conservation would be influenced by only one fact; that is, the yearly cost to the government of maintaining the area benefiting the privilege, and what proportion of the charge should be borne by the power company? It eliminates all questions as to the efficiency of the development or the amount of development, and *hence would tend to make for efficiency and maximum use of the resources.* It eliminates the question of the market value of distance of transmission. The market value would, as it should, depend upon the natural advantages for power development in the district, and there should be no additional tax when high efficiency is aimed at or long transmission is undertaken.

Rights-of-way and property necessary would be a separate matter from the conservation charge, and property rights necessary for development would be not temporary but permanent. We should not expect a man to establish his permanent home and develop his farm if he is not assured title.

The above method of charging separately for lands and for conservation, and giving title to lands, would remove all objection on the part of investors, because then power companies would obtain title to grounds occupied by the development and there would be a definite and fair method by which the conservation charge would be arrived at, now or at any future time. It is believed no logical objection could be raised to the plan by the power companies.

It may be contended by some that the government should obtain as large a revenue as possible for every development and apply the proceeds for the general welfare, the argument being based on the fact that the government grants a privilege which cannot be enjoyed by others and should receive a revenue in proportion to that derived from the operation of the privilege. The examples cited, however, make this position untenable, as the power companies should not be treated differently from the farmer, the lumber company, the railroads, or other interests. There is no monopoly in water power development, and the advantage gained by a man who does something should not be shared by the man not so progressing. It would be just as logical to make the thrifty farmer share with the less thrifty. Industry, progressiveness, and individuality should not be stifled or taxed.

Feed, timber, all crops, minerals, and water, and anything in which nature produces, are primary producers of wealth. Why should water be classed differently from any of the other natural products in the government policy of development and control? The general government cannot justly make a charge equivalent to a franchise tax or regulate rates; those privileges would remain with the state and subject to local laws, where the streams are under State control.

When the conditions of the past, present, and future developments of the country and its industries are considered in relation to the present and future developments of power, it is believed that the only tenable conclusion which can be reached is that the power interests must be treated as other interests and charged for conservation only on the basis of the cost to the government of the thing furnished by the government, and that rights-of-way and property required for the development should be the property of the company making the development. The only varying element, then, will be that due to the fact that the value of the property owned by the government is changing as time advances, and the conservation charge should be changed accordingly.

The conclusions drawn from the above discussion may be briefly stated as follows:

A. A proper conservation charge can be made only on the basis of the cost to the government of that which is furnished by the government.

B. The proceeds from any particular privilege cannot be devoted to any other watershed or any other section, or for any purpose except the particular privilege.

C. The conservation charge will have a maximum limit at any given time which can be determined by calculating the yearly cost of the conservation to the government. This charge can be fixed for a period of say ten years, and at the end of that time a re-calculation may be made, and a new conservation charge made yearly, to meet the changing cost of maintenance.

D. The question of the proper conservation charge is entirely a separate matter from the charge to be made for lands and rights-of-way for development, and the two matters should be kept distinct.

E. Rights-of-way and lands necessary for the development should be charged for on a fair basis of value, as would be determined if the lands belonged to private parties and a value had to be set on them for the power purposes by a court, or a commission. Rights-of-way and lands necessary should be deeded outright by the government to the power company and the only changing conditions then, as time goes on, would be the yearly conservation charge.

My suggestion for a government policy on water-power resources can finally be stated in a single sentence—encourage water-power development as much as possible, make a proper conservation charge and make grants for rights-of-way and lands necessary for development permanent on condition that a certain proportion of the work be done each year, and that a certain proportion of the development be completed within five years when a patent for all grounds occupied will be granted.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29-July 2, 1908.

Copyright 1908. By A. I. E. E.
(Subject to final revision for the Transactions.)

CRITICAL STUDY OF LIGHTNING RECORDS ON TAYLOR'S FALLS TRANSMISSION LINE

(PAPERS BY J. F. VAUGHAN AND N. J. NEALL*)

BY PERCY H. THOMAS

The following study of the Taylor's Falls line lightning data has been made for the purpose of discovering what inferences as to the nature of the attack of lightning on a transmission line can be safely and properly drawn from the unusually complete data recorded.

Interpretation of tell-tale papers. The correctness of all inferences presumably depends on a correct interpretation of the significance of the various types of punctures in the tell-tale papers; hence this matter was given special consideration. A careful study of the original papers shows the punctures in the tell-tale papers taken from the gaps in the ground connection of the insulator pins to be of three sorts.

1. Very fine, almost invisible punctures, usually occurring in large numbers and scattered round a central point or points. These are often so numerous that the paper is actually eaten away for a small space, giving a superficial appearance of the second type. This first type is characterized by a sharp edge, looking almost as though it had been scorched and usually by a few small punctures in its neighborhood.

2. Distinct individual holes, varying in size from that made by a small needle to large holes, all having the appearance of having been torn in the paper. These all have rough hairy edges but show no signs of burning.

3. Individual holes of the general character of the last but with burned or charred edges. This type may show any amount

---

*Presented at New York, May 19, 1908.

of burning from a slight scarring to the complete destruction of the paper.

In general these three types are clear and easily distinguished. They are clearly to be interpreted as follows:

First type. Puncture due to charging current taken by the pin in view of its static capacity to the line wire. This charging current evidently will exist under normal voltage conditions, if the width of the gap in the ground connection where the tell-tale is placed is sufficiently small to be broken down by the voltage normally existing. Trouble was experienced at first from the honeycombing of tell-tale papers during normal operation, since the ground gaps were set too small. The readjustment of these gaps is noticed in the large chart, Fig. 11, under date of June 10. When these gaps were finally set above the breaking limit of the normal voltage, punctures of the first type must have indicated abnormal voltages, and the size of the puncture indicated the amount of charging current taken by the pin or sometimes the number of times such voltages were repeated.

The *second type* above, indicated "spill-overs"; that is, the jumping of a static charge over the surface of the insulator. This was a very common occurrence in these experiments. Spill-overs are distinguished from the first type of puncture by their size. Only the finest punctures can be caused by the charging current to the pin itself, on account of its small static capacity. On the other hand, when the spark jumps from the line to the pin the static capacity of the line comes into play and also any charge coming to the line from the atmosphere and a much larger discharge results.

The *third type* is of the nature of the second, except that after the spill-over, current from the generator has followed.

The following analyses are based on the above interpretation of these paper punctures, which the writer has no doubt are substantially correct.

Analysis of storms. Storm of July 4. This storm is of special interest, since there happened to be no power on the line at the time the storm occurred. The direction of the storm is west to east, crossing the line two miles from Hugo at about pole 918. There are a number of relatively small punctured papers between the main centre of disturbance near pole 918 and the substation; those occurring beyond pole 1135, five miles from pole 918, appear to have been caused by the *first type* of sparking; that is, by charging current to the pin itself without discharge over the insulator. These punctures were made presumably before the taking off of the power from the line on the morning of July 4, or perhaps after it was put back before the papers were taken out on July 6. They may, however, have been made by waves of static from the disturbances occurring near the middle of the line. The first explanation, if true, means that these particular gaps were set so close as to show these fine punctures when there was no noticeable abnormal disturbance.

There seem to have been two distinct local disturbances in the neighborhood of pole 918. A heavy discharge must have struck at pole 918 on all wires and have traveled in both directions on all wires. The spill-overs tributory to this discharge on phase A appeared last at pole 928 in the direction of the sub-station, and at pole 906 in the other direction. On phase B spill-overs appeared last at pole 924 in the substation direction and at pole 909 in the other; on phase C there were small spill-overs to 909 (possibly to 894) and a large one at 924.

There must have been a second discharge near by, according to this analysis, centering at poles 931, 934, and 937. The spill-overs from this disturbance seem to have been confined to poles not distant from the center at pole 934 more than six or eight poles. And although three insulators were shattered near pole 934 there were apparently not more than four other spill-overs. It is possible that the very small spill-overs at poles 955, 958, and 961 were due to this same discharge. Their appearance indicates rather quiet static.

It so happened that this discharge, or these discharges, came on the section of line, a little over a half-mile long, between ground wire A and ground wire B. That this is the case seems certain, for the punctures of the papers are nowhere so large in the general region of that storm as around 918 and 934. It is unfortunate that the storm did not actually strike over one of the sections protected by grounded wire, as this would have given more valuable evidence as to the protective effect of such wires than now exists.

As a matter of fact nearly all of the tell-tale papers in the *ground connections* of the overhead ground wire B discharged enough electricity to show a hole perhaps one-half as large as the largest punctures in the tell-tale papers in the insulator pin-ground wires on the unprotected portion of the lines. These overhead ground punctures, further, grew smaller in size from the end nearest the maximum disturbance to the other end. They are quite as likely to have been caused by the static wave passing down the transmission line from the region of pole 918 as by the direct effect of the disturbance on the overhead ground wires. They may, of course, conceivably be due to a suddenly released bound charge, but they seem to be much too large for this. The evidence against the "bound charge" hypothesis is summarized in the second paragraph below. Two insulators were shattered under this overhead protection, one only one pole within, the other four poles within. This shattering probably had little to do with the effectiveness or lack of effectiveness of the ground wires, since the disturbance arose on an unprotected portion. The grounded wires on the other side of the unprotected portion of the line showed very much smaller punctures in their ground connections and only three in all located next to the end of the section.

The smaller of the two main disturbances, near pole 934, which was the one nearer the last described section of ground wire (type A) was central about seven poles away, while the greater disturbance near pole 918 was central about five poles from ground wire B section. No very satisfactory conclusions can be here drawn as to the protective power of the overhead ground wires, since the storm did not strike so as to give them a trial. It may, however, be safely concluded from the tell-tale papers that the ground wires are very active and pass much current. This is almost certain to be helpful. The other types of overhead ground wires located at distances from one to six miles, seem to have taken no discharge of any particular significance.

It is very important to note the nature of the discharges in the tell-tale papers of the lightning rods that are entirely separate from the line structure. In the case of nearly every lightning rod on the whole system small punctures were observed, usually much less than the size of a normal spill-over puncture on the line, but very numerous. In one case, not near the centre of disturbance by two miles, pole 820, what would be taken as a very severe spill-over puncture if found in the insulator tell-tales, was observed. This must have meant a severe direct stroke. In none of these cases of spill-over size discharges in the lightning rods was there any sign of disturbance on the adjacent portion of the line. From these observations on lightning rods it may be concluded that the disturbances on the line are in all probability due, at least in their severe form, to direct charges from the air and not to the accumulation and release of bound charges on the line. The latter could not occur on the rods; and if the rod discharges come directly from the air, it is evident that the line charges as well do so in the main, since both sorts seem of the same nature and of the same general magnitude. Furthermore, the heavy discharge at the lightning rod near pole 820 should have produced a severe discharge on the line, if the sudden release theory be the right one, for the conditions must have been particularly favorable at this time.

During this very active storm there were only very few discharge indications on the station arresters. At the power-house there were very small discharges on all three legs of the horn arrester. At the sub-station there were discharges, both series and shunt, in leg C on the low equivalent and a discharge in leg A on the electrolytic. This is very significant, for the storm was severe and prolonged in the center of the line and yet was hardly noticeable at the station arresters; in other words, the disturbances did not travel to the station without a considerable loss of energy.

Storm of August 18. This storm followed the direction of the line from sub-station toward power-house pretty closely and caused apparently five principle disturbances. The storm first made itself felt at or about pole 1387, where it caused spill-overs on all three line wires in the immediate neighborhood, especially on A and B. Here it very possibly started a short-circuit on the system through wire B on pole 1387 and probably through either leg A of the low equivalent or the horn arrester at the power house or leg A of the electrolytic arrester at the sub-station. This, then, may be taken as the cause of the dip in voltage referred to in the notes of this storm. Then nearly a mile farther on another discharge of great severity occurred at or about pole 1357. This destroyed several insulators and probably caused another short-circuit through wire C on pole 1341 and through leg A on one of the above arresters or perhaps more than one. This shut down the power house as reported and for the rest of the storm there was no power on the line. There are no more evidences of burning of papers.

Poles 1342 to 1385 had the ground connections removed from the pins and can show the actual discharges only by the shattered insulators and the split poles. Heavy spill-overs occurred on wires A and C on the pole having grounded pins nearest to the disturbance at pole 1351 and spill-overs were continued for nine poles on wire A. Spill-overs on other wires seemed to stop at pole 1341. Two or three spill-overs occurred in the next third of a mile on wire C, the last one on pole 1314, being one of the most severe of the storm. This spill-over was probably due to a separate disturbance.

No more very serious spill-overs occurred, though there was a single one of some violence at pole 909 wire A, four poles under the overhead ground wires, type B. This is significant, since there is no discharge of any importance at all in the neighborhood outside of the ground wire section. A single very severe spill-over occurred at pole 563 on phase C. No other spill-over occurred near it.

Overhead ground wires B were active, since at nearly every grounded pole a hole occurs in the overhead ground tell-tale papers of the size of a large spill-over puncture. There does not seem to have been any other evidences of a discharge in this neighborhood except that at each end of the ground wire section a line spill-over occurs on one wire, though these are different wires, and both are within the overhead grounded wire section. This looks suspicious, as the line spill-overs either cease on the line wires or at least become very much smaller exactly at the ends of and outside of the ground wire sections. There is apparently no evidence to show what is the phenomenon causing this particular condition.

The series coil tell-tale papers in this storm are very significant. The choke-coils at pole 1356, within one pole of shattered insulators on both sides on one wire and very close on all wires, had all three papers burned up, showing a very violent discharge in shunt to the coils, enough to ignite the papers. The papers for the coils on wires A and B at pole 1230 were burned up, this pole being a distance of two and a half to three miles from the nearest disturbance. There is a small puncture in the series coil in wire A at pole 1615, five miles in the other direction from the nearest discharge of any apparent severity. As these coils have only twenty turns of conductor of one foot diameter, probably not equal in inductance to more than a hundred yards of line wire, a very sharp wave-front is shown by these series coil discharges.

The above storms have been taken as samples. The analyses of the others have been made similarly, but the results can be best studied by topics.

Protective power of overhead ground wires. In making inferences on this subject, the most important one of all in some ways, it is necessary to use the greatest caution not to be misled. The data are not as full as was to be hoped but are nevertheless better than any definite data obtainable elsewhere.

Ground wire A. This section was subject to some disturbance, more or less, in five storms. There was one spill-over on an insulator in this protected section due undoubtedly to a disturbance outside the section, and four punctures in tell-tales of equivalent size in the grounds from the overhead wires, all in the storm of July 4. In only one instance was there any violent disturbance in the immediate neighborhood of these ground wires, viz., July 4. This occurred just outside the protected section. The overhead wires did not seem to have much effect. This was not of the most approved form and not much was to be expected of it.

Ground wire B. In case of this section there were fifteen spill-overs of all sizes over insulators under the ground wires and twelve more or less equivalent punctures in the ground connection of the overhead wires. There were six storms in which records are furnished, but only two in which punctures of spill-over magnitude occurred. In one case the centre of discharge was just outside of the grounded section and in the other was directly over it and did not extend outside. In the former case two insulators were shattered, one located one pole inside the protected section, the other four poles inside. This probably had little to do with the effectiveness or lack of effectiveness of the overhead ground wire. In the latter case, where the line showed spill-overs and the attack was in the grounded portion, the discharges seemed to occur near the two ends mainly as though there had been two independent discharges. The protective power does not seem to have been particularly effective here.

Overhead ground C. Records on this section are given for six storms, none however showing any discharges of any serious amount near this section. In only one case was there a noticeable discharge in any ground connection from the overhead ground wire. There was, however, no spill-over on the line wires on this section. This type of overhead ground is not a good one and in no case seems to have exercised much if any protecting power, nor to have had an opportunity to exercise any.

Ground wire D. This section is reported in six storms, two line spill-overs are shown on same pole, and nine more or less prominent discharges in the ground connection of the overhead wires, none being larger than 0.1 in. and most being smaller. No severe storms appeared to have attacked this section of the line. However, the two spill-overs were fairly severe and occurred six poles from the end of the section. The middle pole is eleven miles from the ends.

While the overhead ground sections as shown in the records are very active in discharging current, it is doubtful whether any of them would be wholly effective, as installed, in protecting the line wires from every severe discharge, such as occurred a number of times on this plant. It seems probable that the line wires would share the most severe discharges that attack the ground wires; the danger is that the latter are neither well enough spaced from the line wires nor often enough grounded completely to protect the line wires.

Lightning rods. There were six spill-overs on the line on the section protected by type A lightning rods on pole tops in five storms, and four more or less severe punctures in lightning rod papers. In the storm of August 4 and 6 there was one severe discharge in which there were three insulators shattered on this section and some very severe spill-overs but the lightning rod papers seem to have been omitted or destroyed, except a few at the end away from the disturbance. A very severe discharge occurred at pole 1028 three poles from the lightning rods, but no noticeable discharge occurred in the ground connections. The line, however, was evidently not protected. Although the rods will undoubtedly take such discharges as come to them, they probably cannot be relied upon to protect the line wires and insulators. They will undoubtedly, except in very extreme cases, however, protect the poles from injury.

Lightning rods B. These rods showed minor activity in all or nearly all storms, and greater activity in the three August storms which were centered within five miles or less of this section. This activity consisted in a multiplicity of very fine punctures aggregating a good size hole in the case of some ten or twelve rods. In addition on July 4, there was a violent discharge showing what would be considered one of the most violent spill-overs in an insulator pin ground. The center of the July storm was over two miles away, but some smaller disturbances evidently occurred nearer to this special arrester discharge.

Lightning rods C and D. These showed very much the same phenomena as the other types: activity with small punctures, many per paper—in about one-fourth of the rods—nothing on many of the intermediate poles. The active poles were pretty evenly distributed. There were no disruptive punctures of magnitude in the lightning-rod grounds. There were, however, no disturbances in the immediate neighborhood of these rods.

Line choke-coils. Choke-coils were located at poles 986, 1203, 1356, 1615. The storm of August 18 was severe at pole 1356 and moderately severe at poles 800 to 900. The tell-tale papers at pole 1356 were all burned up, these at pole 1203 three miles away were burned up in wires A and B, and a fair-size explosive puncture occurred at pole 1615, five miles away. Three good size punctures occurred also in the coils at pole 986 in wires B and C about two miles from the nearest disturbances.

This appears to show that charges of some magnitude pass along the line or possibly that their effect is increased by oscillation. It must be remembered that a ground on the line, lasting for even a very small fraction of a second, will cause the full static charge of the line on the one side of the choke-coil to pass by to earth, not merely a charge received from the air. Also that a burned paper is quite likely to be merely ignited by a spark of some violence, when it may be subsequently consumed by natural causes. This action is known to have actually occurred.

EFFECTIVENESS OF ARRESTERS.

Storm of June 25, not severe. A relatively small but sharp discharge occurred at pole 1571, four and a half miles from the sub-station. Small static discharges occurred on one leg in the sub-station low-equivalent arresters in both series and shunt gaps and on one leg in the series gaps only. On the electrolytic at the sub-station, discharges occurred in all three legs, and two showed the following of a small quantity of generator current. The discharge on the line caused spill-overs on all three wires at the same pole. The low equivalents at the power house did not discharge.

Storm of June 29, not severe. This storm showed no spill-overs except the shattering of two insulators at poles 1474 and 1478 causing a short-circuit. There was no evidence of a discharge on the low-equivalent arresters at the sub-station, seven miles away, nor on the electrolytics at the same place.

The plant was shut down by this experience. There were no arrester discharges at the power house.

Storm of June 30, *not severe.* In this storm which attacked the line four miles out from the power house, all legs of the power-house low-equivalent arresters discharged, showing signs of dynamic current in the series gaps, but only a good static puncture in the shunts. The power-house horn arresters discharged only in leg B, but showed a heavy burning in the tell-tale paper of the resistance shunt ground connection, and a smaller burning of the paper in the main ground. These discharges of this storm out on the line were relatively severe and eight insulators were shattered, distributed on all three wires. No injury was done to station apparatus. On legs A and C the only arrester to discharge was the low equivalent. Furthermore, on line wire C there were two heavy spill-overs only a mile from the station, and two more spill-overs a little farther off. The sub-station arresters showed no signs of discharge. In all probability there was no discharge on the line within some 35 miles of the sub-station.

Storm of July 4, *severe, no power on line.* Although this storm, which has been already analyzed, was very severe, no great disturbance was manifested at the stations. The disturbance was centered at the middle of the line about 20 miles from each end. At the power-house the horn arrester discharged in all phases and the low equivalent probably in leg C, series and shunt, and the electrolytics at the sub-station in leg A. The discharges in the horns were small while those in the others were relatively large. The low equivalents at the sub-station discharged faintly in leg C. This is an interesting case, showing that the very severe discharges do not necessarily carry with power for half the length of the line. The nearest real spill-over to the sub-station seems to have been at pole 1135, 14 or 15 miles away though a number of quiet static punctures in papers occurred around poles 1500 to 1600. The nearest spill-over to the power-house was the main disturbance over twenty miles away.

Storm of July 13 *and* 14, *not severe.* A sharp stroke occurred at about a mile and a half from the power house, shattering two insulators on wire B and causing a number of spill-overs on wire C. At a point three miles from the power-house on wire A, there was an uncertain sort of burning in tell-tale which may have been a severe spill-over but probably was not.

At the sub-station the horn arrester discharged in all legs. The electrolytic showed a heavy dynamic burn in leg A, and static in leg C. The low equivalents showed nothing. At the power house the low equivalents showed small burns in legs A and B, and the horn in B, with static in A and C.

Storm of July 19, *distant from line.* There was considerable quiet static near the center of the line and many of the lightning rods showed small punctures, as did the overhead ground wires. There were however no spill-overs and no arrester discharges on either end of the line. This storm was said to be distant. Some of the punctures in the lightning rods are given as over 0.04 in. in diameter. They must have been caused by repeated discharges of very small magnitude.

Storm of August 1, *distant from line.* This storm was similar to the last storm except that the lightning was distant to the west instead of to the east. There were no spill-overs and no activity in the lightning rods nor in the overhead grounds. None of the arresters discharged.

Storm of August 4 *and* 6, *severe, parallel to line.* This storm was very severe at a point about 14 miles from the sub-station, and showed almost no activity at any other point, except that through the central portion activity was evident but in no very great violence. There are one or two doubtful spill-overs recorded nearer the sub-station. Except for a good clear static puncture in the ground connection of the power house horn on leg C, there was no discharge at the power house. At the sub-station, on the other hand, there were discharges in all legs of the horn arrester; in legs A and B, small in volume but perhaps as large as the 5,000 ohms series resistance will permit, and very numerous; and the tell-tale paper was nearly burned up in leg C. The electrolytic at the sub-station showed static in leg A, a small amount of burning in leg B, and also a second static discharge, and no discharge in leg C. The low equivalent at the sub-station showed a discharge of fair size in leg C, but no burning. The Hugo arrester showed discharges in the first gap in all legs, and in legs A in addition a heavier discharge in the next gap which has a less series resistance. The Hugo arrester is only three-quarters of a mile from the nearest severe discharge, occurring on leg A, which is the leg on which the discharge in the second arrester gap at Hugo occurred. This case is a good example of how quickly the energy of a traveling wave can lose its intensity.

Storm of August 8 *and* 15, *severe, parallel to line.* This storm passed from the sub-station up the line but was not severe. There were a few scattered spill-overs but no broken insulators. One heavy discharge occurred on leg *C* at pole 1434, about 7 miles from the sub-station. At the sub-station the horn arrester discharged in all legs and held dynamic current in leg *C*. The only other indication of holding of current on any other leg is at the power house in leg *A* in the horn. Discharges occurred in all legs in the Hugo arresters and in one case in all three gaps. This suggests that the test on the arrester is more severe when there is no spill-over; this seems reasonable, for the line then has no relief at the point of attack. At the power house the horn discharged in all three legs and held a little in legs *A* and *C*. The low equivalents discharged in the power house in leg *C* and held the arc a little in the series gaps; static only appeared in the shunt. The electrolytic discharged at the sub-station in leg *B*.

Storm of August 18, *very severe—parallel to line.* This storm passed up the line just as did the previous one and had a severe spill-over at a point about 10 miles from the sub-station and another at about 19 or 20 miles and a small one at 12 miles from the power house. At the sub-station the horn arrester discharged in all legs, the electrolytic in legs *A* and *B*, and the low equivalent in leg *C*, series and shunt. The electrolytic seemed to hold a little generator current. The Hugo arrester discharged in all phases in the first gap and in the third gap on legs *A* and *B*. At the power house discharges occurred in all legs in the horns and the low equivalent.

Storm of September 6, *not severe.* No spill-overs occurred on the line except two or three near the center. There were numerous quiet static puncturings throughout the length of the line. The only arrester activities were at the sub-station where quiet disturbances occurred in legs *A* and *B* on the horns, in leg *C* on the electrolytic, and leg *A* on the low equivalent. The storm was to the east of the sub-station and not directly on the line.

The remaining storms can be briefly summarized. On the 16*th of September* a storm crossed the line at the power house and caused two shutdowns. All legs of all power-house arresters discharged in all gaps, and there was one spill-over on wire *C* near the power house, within a few poles of the end of the line. The horn showed hold-over current in all legs, the low equivalent in only leg, *B*, and not much there. At the sub-station discharges occurred in the horns in legs *A* and *B*, and in the electrolytics in legs *B* and *C*. There was one discharge in each leg at Hugo.

On September 18, spill-overs occurred on all wires about six or seven miles from the sub-station. Discharges occurred in the sub-station horns in all legs, and in the electrolytics in legs *B* and *C*. No other discharges on the system.

On September 19, a storm 11 or 12 miles from the power house caused a discharge in all three phases in the horns in both stations and in phase *C* at the Hugo arrester. No other discharge occurred.

General. An examination of tell-tale papers shows that the sub-station horn with 5,000 ohms resistance in series showed only very fine punctures, showing great limiting of discharge. The horns at the power house having about 500 to 600 ohms of series resistance, and all the low-equivalent arresters, showed considerably larger punctures indicating a freer discharge, while the electrolytic would probably show a still larger puncture except for the fact that the charging current to the arrester itself, which usually follows the discharge for a few moments, burns the paper and enlarges the static punctures, so that it is nearly impossible to determine the size of the hole made by the static. Of course, a holding of the generator current will mask the static punctures; this often happened with the horn arresters as well.

It seems highly probable from the data as to the discharges of arresters that the sort of disturbance making the heaviest demand on the station arrester is the stroke on the line which is nearly but not quite sufficient to cause a spill-over. This disturbance may send a wave the length of the line sufficient to cause arresters to discharge, but not severe enough to be more than the arresters (in this case at least) could handle. These waves go far but they are not enormously severe. This is an important conclusion. The cases in which a much more severe attack on the line causes a spill-over does not send as severe a wave to the station apparatus as the latter type. This is natural as the spark once established to ground will readily discharge most of the severity of the disturbance which would not have been able to get to ground without the actual establishment of a ground arc. Exception is here made of course to the direct stroke of great severity at the station which still remains the most dangerous of all lightning attacks. It is interesting to note that the storm of September 16, occurred at the power house and that no damage was done to apparatus, though the arresters showed vigorous action in all gaps. This could not have been a very severe disturbance.

The arresters seldom if ever, during this season seem to have been put to the limit of their ability to care for the discharges. In no single instance on any one leg did all the sub-station arresters of various kinds discharge at the same time in all gaps. The Hugo arrester discharged in all three gaps only once and then in only one phase. At the power house, omitting the storm of September 16, which occurred at the power house itself, there were only three cases where all the available gaps on any leg discharged, and in one of these cases the severity of some of the discharges was not the maximum. This is important, and is part of the evidence tending to show that the waves coming in to the station (omitting again the direct stroke at the station itself) are not of enormously great volume or energy or voltage and can be properly handled by non-arcing arresters, even of the series resistance type. This conclusion is of the greatest importance, and seems very well substantiated by the data of this paper. Of course, the insulation of this line is not as high as can now be obtained through the newly developed insulators on the very high voltage lines, so that more severe waves must be expected to appear at the stations in some of the systems now building, but the principle is the same and additional insulation strength can if necessary be given to station apparatus and circuits.

From this line of reasoning; namely, that the limit of discharge capacity of the arresters was not reached, it may be concluded that the so-called sensitiveness of discharge, at least as between the arresters installed in this plant, is of relatively no moment. Since the arresters have been able easily to care for all discharges, and since they have discharged often but rarely if ever to their limit of capacity, any greater sensitiveness would add nothing. In fact the less sensitive the arresters the better, as long as protection is secured. A certain risk is run every time that an arrester discharges, and they should act only when necessary to protect the line. The quality most requisite is the freedom of discharge. Furthermore, any degree of sensitiveness may be obtained by the proper setting of the initial gap and any arrester can be set as sensitively as necessary, provided only that it still remains non-arcing.

The following is a summary of the relative action of the various arresters during this season:

At the sub-station	Discharges.
Horns without low equivalent or electrolytic	12
“ “ “ “	21
“ “ electrolytic	15
Low equivalent with electrolytic	2
“ “ without “	6
Electrolytic “ low equivalent	12

It thus becomes evident that the horn arrester is here set to be the more sensitive and always responds, and that if either one of the others starts it prevents a discharge in the third. It must be noted that no direct discharge on to the line occurred near the sub-station.

At the power-house.	Discharges.
Horn without low equivalent	7
“ with “ “	10
Low equivalent without horn	$2\left\{\begin{array}{l}\text{before}\\\text{resetting.}\end{array}\right.$

The same conclusion follows here as from the sub-station data.

It is probable that the horn arrester when using series resistance is not a free discharge but that either of the other types were, since they would seldom discharge together.

As to non-arcing power, it may be said that the horn with resistance and the other types were non-arcing on this plant which has a relatively limited power behind it, but that the horn without resistance was not non-arcing. This is as expected, and is shown by the numerous records of the opening of the circuit breakers.

Shattering of insulators. This is a most important and instructive study. Out of forty-two injured insulators only three were punctured. The others were shattered, that is, had their petticoats cracked or broken without any direct puncture of the porcelain. The cause of this phenomenon, at least in the case of these results, must be taken to be the shock of the static and not at all the effect of the generator arc, as is frequently supposed, for in the storm of July 4 there was no power on the line and eight insulators were shattered. This shattering sometimes does and sometimes does not cause a shutdown. This direct shattering of insulators without puncturing by the lightning is startling and undoubtedly indicates that the discharge is very abrupt and violent, it further indicates the difficulty of testing insulators for actual service conditions by laboratory apparatus. In addition to the 39 shattered insulators there were nearly 150 spill-overs that did not cause injury to the insulators. Inspection of tell-tale papers shows that these spill-overs were often just as severe in many cases when no injury was done the insulator as in the other cases. Although the data in the paper do not enable a conclusion to be definitely drawn, it seems true that many of these spill-overs occurred without shutting down the plant.

From the general appearances of the disturbances it seems a fair inference that, while the number of spill-overs was undoubtedly increased by the presence of the ground wires to the pins, there would have been many such discharges in any case. This view is supported by the breaking of insulators in the storm of August 18, when there were six insulators shattered in a section of line where the ground connections had been removed. A most important result follows from such a premise. If the discharges that are to be expected are irresistable and are going to ground in any case, then the great cost and mechanical complication that is proposed for many high voltage plants may fail to serve the purpose expected. And also a second most important conclusion—which is nothing but common sense and has already been sometimes recognized—every insulator should be so constituted as, when subjected to an irresistible potential, always to fail by discharge over its surface and without cracking, for then often little or no inconvenience or delay will result, while if the insulator is broken or punctured, an interruption and long delay for repairs may result. This point cannot be too much emphasized. This ideal condition seems to have been pretty well realized at the Taylor's Falls plant as far as freedom from insulator puncture is concerned. If each spill-over had been a puncture it is easy to see what a serious menace it would have been.

Character of individual discharges. A careful examination of the distribution of punctures and spill-overs indicates with considerable certainty that a given disturbance attacks the line at a very definite point and may either go over or through an insulator to ground, or if unable to do this to pass along the line to find a weaker spot or to wear itself out. It is certain that such a discharge, at least in this plant, will pass by at least three to six ungrounded poles to go to ground over a pole with a grounded pin. These pin grounds occur every third pole. This means that the front of the static wave does not drop as much in potential along the line for three poles as the difference in the insulation strength between the grounded and the ungrounded poles. On the other hand, the wave will not pass by, perhaps ten poles, to discharge over one of the grounded pin poles. This indicates that the drop of potential in the wave front is greater in the ten poles than the difference in pole insulation strengths. The latter data come from the storm of August, 18 where six insulators on ungrounded poles were shattered within less than ten poles of grounded pins. In other words, not more than a thousand or at most a few thousand feet of the wave front will have travelled by an insulator before the maximum or at least the spill-over point is reached. This steep wave front corresponds to a very high frequency. It is well to notice in this connection that the feature that is of importance is the steepness and magnitude of the wave front of the initial discharge and not the frequency in the usual sense as is generally assumed In rapidly decreasing oscillations such as characterize static discharges, if a break-down does not come at the first wave it is not likely to come at all. There can be no proper frequency unless there are several complete cycles established and the formulas for steady alternating currents do not apply even momentarily for the initial wave front.

Damage due to a given storm is not usually limited to a few poles, it is limited but may often extend over a mile or two of line. This indicates that in a given stress locality there are a number of more or less individual discharges due to the same general conditions yet separate in space and perhaps a little in time. This conception seems very reasonable.

It appears to the writer that the spill-overs that have been here considered are largely due to direct strokes, major or minor, actually reaching the line wires. Not necessarily all of great magnitude, such as the strokes that are visible for miles, but large enough perhaps for discharging a relatively small area or volume of air, even only a few hundred feet in extent. This seems almost an inevitable conclusion from the Taylor's Falls data since the lightning rods several times showed tell-tale punctures in the ground connections exactly similar to the punctures in the pin tell-tale papers. These lightning rod punctures could not be due to released bound charges as the static capacity of the rods is too small. It is further hard to conceive of such concentrated discharges as are shown being due to induction from a distant cloud. Again it is difficult to see how enough energy can be stored in a short length of line wire such as seem to take part in most of these disturbances to do the damage that is manifest in the actual case. For these reasons and for others the writer considers these data strongly to confirm his previous opinion that disturbances of the general nature of these shown here, which are almost universal in transmission lines, are due to direct discharges of electricity at high potential out of the atmosphere onto the line wire.

A careful study of all the tell-tale papers in relation to their phase relation and their position on the poles shows that in a large majority of cases of isolated single spill-overs, the top insulator is not the one affected. The fact is marked when the total number of the specific instances recorded are considered. This has a most important significance, for it can indicate only that the charges approach from the side before the actual discharge rather than from the top, straight downward. On consideration this seems to be the natural course, for although any gradually approaching source of disturbance will tend to come downward gradually, yet at storm times there are always strong currents of air along the ground which would certainly overbalance any downward motion. Downwardly moving air can have no place to go without passing to the side after reaching the earth, so that it is extremely probably that the course of the air will always be along the ground with a slightly upward or downward motion. This means that the chances are that the side wires as well as the top wire will sometimes be reached by a discharge. Of course, this does not mean that the top wire will never be struck nor that the same exact phenomena will be found everywhere else as in this case, but in such matters as the locating of ground wires this possibility must be clearly borne in mind.

Furthermore, in some eight or ten cases of the most severe discharges the same pole shows spill-overs on all line wires, one of which (usually a side wire) is generally much lighter than the other two. This suggests the probability that, after such a very severe discharge has jumped onto one or two of the line wires, their potentials are so raised that they cannot contain the discharge and it jumps to the third wire. This will be of course on account of the impedance in the ground path. This does not seem perhaps a remarkable conclusion but it leads to an important inference, namely, that if overhead ground wires are to protect they must be so far spaced from the line wires as to prevent a discharge thereto. It is evident that the power of these overhead ground wires to carry a discharge to ground and prevent its jumping to a line wire will depend on the nearness of its ground connection to the point of attack. With such discharges as have been found in this case, which are undoubtedly typical of most plants, a ground connection more than a few poles away would be entirely inadequate. It is not so necessary that this ground be a perfect one, as to some extent any local rise of potential at the ground connection at the foot of a pole would tend to protect the line wires on the same pole.

Origin of lightning. Before summarizing the above discussion, it will be interesting to speculate a little about the nature of the phenomena in the clouds from which these disturbing actions come. According to a recent hypothesis, the rise of potential in the clouds is as follows: by some cause, perhaps the action of the sun's rays, there is produced a more or less gradual ionization of the air in certain strata of the atmosphere some distance above the earth. This produces electrons, (or negative charges) and positive ions, (which are loose atoms of matter with a positive charge). At the same time there is usually an accumulation of water vapor in the locality. It is known by laboratory experiment that at a certain pressure, water vapor will condense on electrons. Whenever the necessary pressure of water vapor is reached undoubtedly such a condensation will occur and these electrons, being loaded down each with a drop of water, will fall to the earth or toward the earth, leaving the positively charged ions suspended in the air. This will, of course, raise the potential of the positive charge, the energy for which process comes from the potential energy of the water drop, which it possesses in virtue of its elevation and its attraction by gravity. As this action goes on, there is produced a higher and higher potential of positive electricity built up by the step-by-step withdrawal of the electrons by weight of the condensed water vapor It may also be assumed that the water vapor goes on increasing in pressure in the upper region until finally, at a much higher pressure than before, the vapor begins to condense on the positive ions and they also then come down gradually.

Now as the two charged layers of air, positive and negative, will usually be widely separated by the wind and other agencies, there will exist throughout the region, charged bodies of air or mist which are some positive and some negative, the negative getting to the earth first or being carried to some other point, while the positive electricity (the usual polarity of the clouds) remains.

When, however, any two of these highly charged bodies of air of opposite sign come into the same neighborhood, there will be a discharge between them, if their potentials are high enough. This will be the well-known lightning in the clouds. Or if a positively charged region does not find an opportunity to discharge to a negative region in the air, it will gradually approach the earth and then discharge to ground.

Suppose that at the end of a hot day a highly charged layer of relatively cold and heavy air has accumulated above a warmer uncharged layer below, which has been heated by contact with the earth in the sunlight, much as a layer of oil may be made to support a layer of water above it, momentarily. The equilibrium is evidently unstable and the layers will overturn at any opportunity. When this process starts the cool air will break through the lower layer of hot air and the whole cold body of air, which is heavily charged electrically, will come to the earth at some point while the hotter uncharged air will move to one side and upward to make way for it. This action suggests the cold breeze which so often accompanies a lightning storm. In this case, of course, all the charge of the air will be discharged into the earth at or near the point at which it breaks through the warm layer either in a few heavy strokes, or, more likely, in a few heavy ones and a great many smaller ones, ranging all the way in size down to brush discharges to earth or accumulations of charge on a line, where there is not enough power to make a direct discharge.

Now this hypothesis accounts very nicely for the tentative assumption that a number of relatively severe flashes occur in one immediate neighborhood, practically simultaneously but not identical and not in exactly the same position. There is a large bulk of air to discharge and each discharge relieves only its own immediate region which is accessible to its discharge path. Other regions in the neighborhood may have no discharges at all, for the cold or charged air has come down only at a relatively few places. There would presumably be other more or less distant locations where the upper cold air layer would break through again and repeat the phenomena.

It is interesting to note that the effect of these ions on the air where a discharge is imminent, especially in the upper air, is greatly to reduce the jumping voltage of the intervening distance. This is the well-known action by which one arc will start another, and indeed is the process by which the arc itself is maintained when once started. It is the presence of the ions and electrons in the arc path, which allows the normal voltage to maintain an arc which may be so much longer than the distance that normal voltage will jump in the first place. If it be assumed that the number of ions in the upper air be considerable, this may mean that the jumping distance through the air in the region may not be so very much greater than the arc-holding distance. This would go far toward making the great length of many lightning strokes seem reasonable, especially in view of the generally accepted hypothesis that the long discharges are progressive, that is, made up of a great many shorter ones, following in quick succession. All the above discussion is purely speculative, but it helps to give a concrete idea of actions that are regularly observed.

Summary. The net result of these various considerations may now be summarized. The Taylor's Falls system as here reported was disturbed from time to time in particular localities along the line by lightning. In each such locality, the extent of which rarely extended over more than a mile or two, there were usually several more or less severe discharges which struck the line wires from the atmosphere. These charges when relatively mild charged up the line and sent waves of static in both directions along the line without spilling over . These waves though of diminishing volume were able to pass many miles and still cause arresters to discharge at the stations. These waves, however, were entirely within the power of the standard arresters at the stations to discharge to earth. This must inevitably be the case since the wave energy has to be carried along the line and by the capacity of the wires and the insulation strength of the insulators.

When the discharges striking the line are too severe for the insulators to withhold, however, they pass over or through the insulator to earth. This may or may not cause a shutdown, a fractured insulator, or an injured pole. In the great majority of cases here reported none of these resulted, unless it may be that shutdowns were frequently brought about. The data are not quite complete on this point. In going to earth these discharges will choose a path to earth not more than a few poles from the point at which they reach the line. They will exert a preference for the weakest of the two or three nearest poles, provided the difference in insulation strength is great, but they will not go much farther for a ground, probably even for a dead ground.

Also in this case in which spill-overs occur, waves of static are sent in both directions along the line but in view of the discharge to ground at the starting point these waves are very likely to be of less intensity than the waves produced by discharges into the line not quite severe enough to cause a spill-over. Thus a mile or two from one of even the severe strokes on the line the effect on the system is not especially severe.

The abruptness of the wave front of these discharges is of the order perhaps of that of a periodical oscillation of 100,000 per second, though it may vary through wide limits. Extra severe discharges when they come are almost sure to reach all three line wires at the same point, though it seems entirely probably that, at least in this plant, the discharges from the air do not strike directly downward but come in from one side or another.

In this district the discharges striking the line were sometimes very severe, so severe that they jumped freely to earth over insulators, cross-arms and poles, and with such static shock as to crack off petticoats in the absence of generator current.

Little protection is obtained from lightning rods located beside the line. Whether protection will be obtained from overhead grounded wires or not depends entirely on the arrangement of wires, the frequency of grounding, etc. Station arresters of the best types should, in the absence of severe discharges close to the station, protect adequately the station apparatus if properly insulated.

Horn arresters as here installed with some paths to ground without adequate series resistance, are not non-arcing and can be relied upon occasionally to shut down the plant. On the other hand, both the electrolytic and the low-equivalent arresters showed themselves properly non-arcing and caused no trouble on this score. The size of punctures in tell-tale papers produced by the discharge of one of the *waves of static* after passing along the line in the worse case does not exceed a very few hundredths of an inch in diameter, while the disturbances striking the line directly caused enormously greater punctures in the pin grounds, sometimes measuring an inch or more.

The above conclusions apply strictly only to this line and to this particular season, but it is evident that the nature of the phenomena must be essentially the same in most cases; and by making a common sense allowance for different conditions and different numerical values of voltage, insulation strength, capacity, etc., the present results can be applied to almost any high tension line.

In the operation of any high-tension system, it should be a strict rule to record and analyze all important breakdowns, use tell-tale papers and other recording devices where practicable, and to require reports of observed conditions and otherwise to arrive at the actual nature of the disturbances at the particular plant. This method of procedure though irksome, especially at first and if not systemized, will go far in the long run toward obtaining the most satisfactory operation. The educational effect on all persons concerned is in itself very valuable. Further, it forms a basis for future review of the situation should that become advisable.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29–July 2, 1908.

Copyright 1908. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

DOUBLE-DECK STEAM TURBINE POWER PLANTS

BY J. R. BIBBINS

In the rapid development attending the introduction of the steam turbine, there has been but comparatively little tendency to introduce radical departures from accepted engine practice. The most important changes have taken place in the boiler room, while in the rest of the plant very few changes have been inaugurated other than a general increase of compactness in the turbo-generating room. Outside of the tendency to structural foundations for generating units, there is little opportunity for originality in design without involving a radical change in the ensemble.

There are now in service three important examples of a new type —the double-deck station. This type of station embodies striking originality in its departure from long-established practice, and in a most fortunate manner reserves for the turbine the benefits of certain advantages inherent to this high-speed prime mover. And it is the object of this paper to present in a general way some of the engineering features of this new type of station which, the author believes, deserve careful consideration and ultimate acceptance as standard, at least for power sites of restricted area, as in cities, harbor frontages, hillside locations, etc. No attempt can be made at this time to make more than a cursory study of the important technical points involved, to each of which might properly be devoted an extended investigation.

The West Point station. At the outset it will be well briefly to review the most characteristic features of this station before proceeding with a discussion of the double-decked type in general; the features are:

1. Generating machinery above boilers on second floor of station.

2. Weight of generating apparatus supported entirely by steel building skeleton. All footings carried down to the same stratum—rock. Box columns 27 ft. high.

3. Floor structure continuous, tied in from wall to wall, thus reinforcing over entire structure.

4. Water-cooled floor column passing through middle of boiler setting to reduce weight and cost of beams spanning battery; all other columns straddle boiler setting.

5. Barometric condenser hung from floor girders directly under turbine exhaust nozzle. Designed for moderate vacuum; no air pumps; adjustable cones; centrifugal type circulating pump.

6. Steam piping simple and direct with few bends, draining back from turbine throttle; no superheat; separators in each supply line to turbines.

7. All important steam header and supply lines controlled by pedestal extension valves from turbine floor; non-return valves in delivery from each boiler to prevent back-flow.

8. Header serves largely as equalizer, hence small in size (8 in.); sectioned by valves; operates practically on the unit system.

9. Designed for 200 lb. pressure, high steam velocities; largest steam pipe in plant 8 in., hung from girders.

10. All auxiliaries steam-driven for feed heating; open type heater; feed taken from condenser hot well.

11. Circulating pumps interconnected for relay working, primed by steam syphons or service pump.

12. Pump suctions submerged 8 ft. in intake bay to avoid surface air; no foot-valves.

13. Two-story side addition accommodating transformers; control and protective apparatus above; heaters and auxiliaries below; also serves as transmission tower.

14. Operating switchboard located in division wall, leaving a clear rectangular operating room, and separate switch room.

15. Generators air-cooled by positive blast piped from outside to reach cooler air and to avoid the possibility of steam from boiler room reaching insulation.

16. Turbine bedplate leveled on plate girders throughout its length with cast lead pad 1 in. thick.

17. Reserve exciter unit, steam-driven, exhaust to heater.

18. Transformers mounted on trucks to facilitate replacement by reserve unit provided.

19. Ash hoist to be installed from level of ash tunnel to level of siding track.

20. Crane reaches basement through removable section of flooring.

21. Flue connections direct to stack; no bends.

22. Self-supporting, brick lined, steel stack.

23. Elevated tank in turbine room to provide head for gland water and building service.

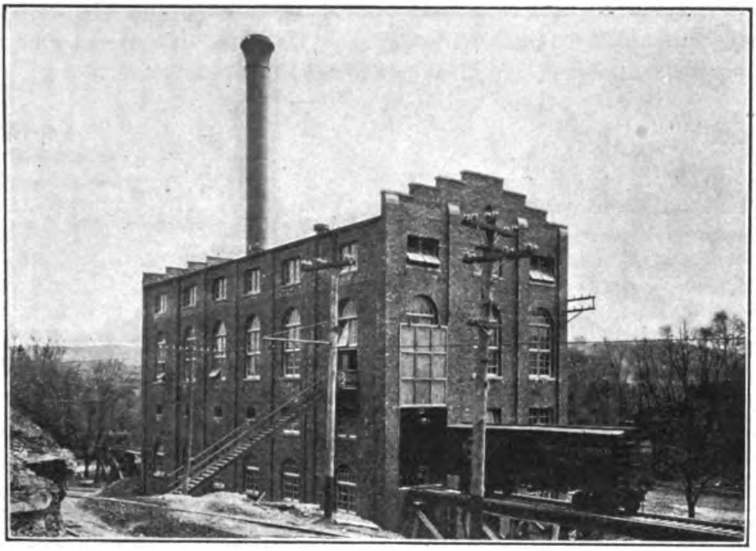


Fig. 1.

The West Point station was designed to serve interurban railway lines through alternating-current sub-stations, and its location is reasonably near the ultimate center of the system. It is but a short distance from some coal mines owned by the company, and the site chosen, at the foot of a hill, permits the use of the impounded waters of two passing streams for condensing purposes. With this site, coal-handling machinery was avoided and barometric condensers used, these several factors combining in the form of the double-deck arrangement.

Compactness. As this is perhaps the controlling feature, it is interesting to note that the problem now lies not with the generating, but with the boiler plant. Familiar Corliss engine practice of a decade ago, involving parallel engine and boiler rooms of about equal size, has been superseded by a ratio of one to three, or more, in turbine plants, especially if the boilers be double-decked, as in the large New York plants. It might, then, seem unwise to return to a station arrangement of equal area, as in the two-story building; but it will be found that other advantages accruing in the direction of cost and simplicity render this arrangement most effective, especially as the extra space in the turbine floor is usually occupied by direct-current converting apparatus serving nearby sections of line.

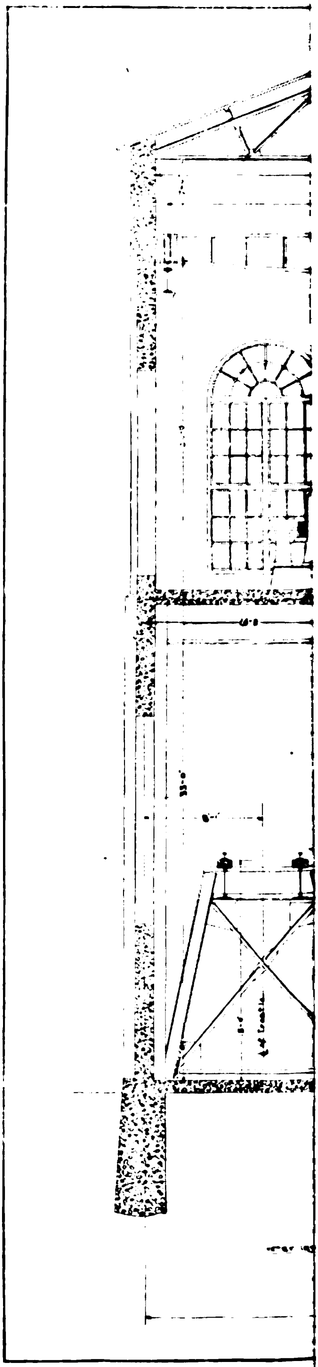
For several years there has been a continual reduction in the bulk and cost of the turbine unit. To what extent, can best be appreciated by comparison with Corliss practice.

Type of prime mover.	Over-all floor space, square feet per electric horse power.
Horizontal Corliss, 500 to 1500 e.h.p.	0.7 to 1
Vertical Corliss, 1000 to 3500	0.35 to 0.4
Horizontal vertical compound Corliss, 7000	0.46
Vertical 3-cyl. Corliss, 5000	0.2
Single-flow turbine, 1000 to 5000	0.17 to 0.75
Double-flow turbine, 15,000	0.05

Thus, in large sizes, the turbine has reduced floor areas to about 20 per cent. of that required by the modern vertical Corliss engine, and to about 10 per cent. of the horizontal vertical type. A detailed comparison between single-flow and double-flow types follows:

Unit size. kw.	Type.	Floor space required per sq. ft. per kw.	per e.h.p.
1000	Single-flow	0.200	0.149
1500	“	0.165	0.123
2000	“	0.141	0.105
3000	“	0.101	0.075
5000	Double-flow	0.092	0.068
10000	“	0.063	0.047

Similarly in weight per kilowatt capacity. Data are not at hand for comparison with complete reciprocating units, but without generators, large vertical Corliss engines, including flywheel, weigh from 320 to 500 lb. per kilowatt, the weight increasing with the size, whereas the large turbine unit complete



(Bibbins Double Deck Plant.)

weighs but a fraction, 15 to 20% of the above, and, moreover, the weight decreases with the size. Considering in addition that the horizontal turbine permits the installation of auxiliaries beneath, this extreme compactness practically eliminates it in the study of reduced floor area.

The West Point station covers a floor area of two square feet per kilowatt. Considering the small size, this represents a high degree of compactness, relatively better than in some large turbine stations. The Ft. Wayne double-deck station covers 1.42 square feet per kilowatt, ground floor plan, the New York Edison Waterside, No. 2, 0.818, and the Boston Edison 2.64, these latter, twenty to twenty-five times the capacity, and one with double-decked boilers.

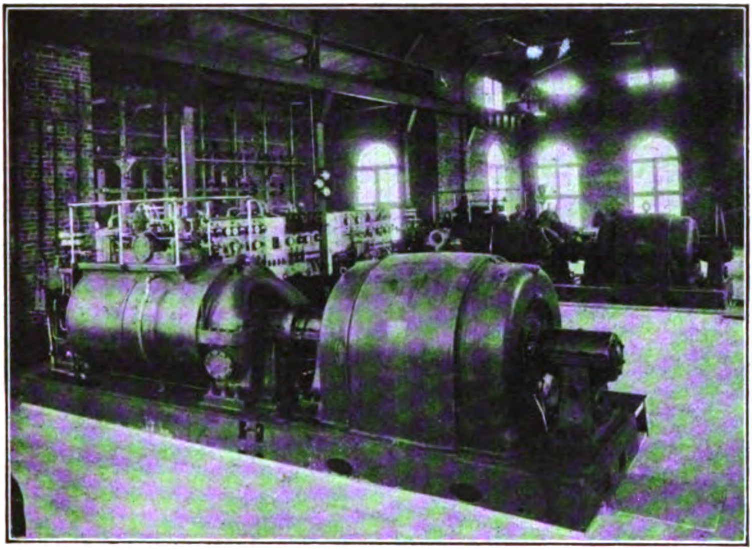


Fig. 3.—General view of operating room.

Building and foundation construction. In spite of the relatively high speed, the construction of turbine machinery has been brought to such a state of perfection that structural foundations are permissible in certain types, which at once opens up an extensive field for originality in the arrangement of units and auxiliaries. For example, 1000-kw. units in a power house at Piedmont, W. Va., are supported entirely upon 8-inch cast iron pipe columns with units spaced 10-ft. centers, and all auxiliaries beneath. In a power house in Philadelphia, reinforced concrete posts tied into the concrete floor structure carry the entire weight of the generating plant. As the height of these columns is 20 or more, it is but a step further to employ standard column sections and elevate the machines to a height sufficient to place the boilers beneath. This has been done in the three stations already referred to. At Fort Wayne the turbine floor stands 28.5 ft., and at West Point, 33 ft., above he boiler room on ground floor, by no means an excessive height.

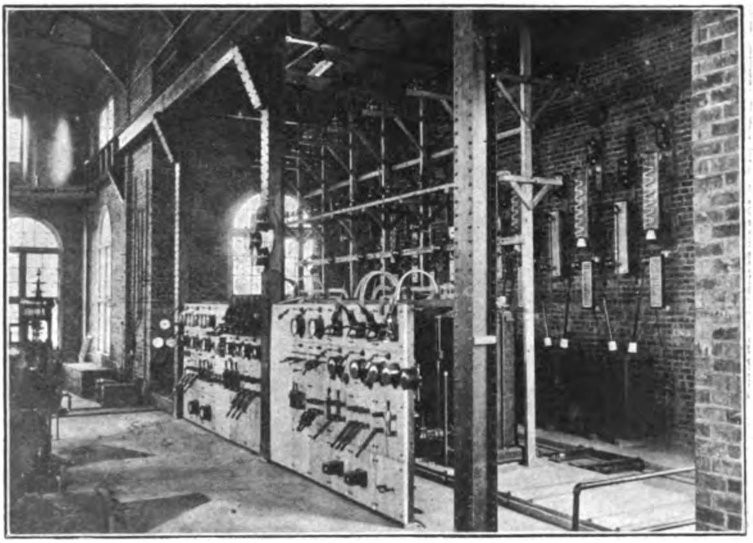


Fig. 4.—Switch room, West Point.

Here seems to be one of the most advantageous features of the horizontal type turbine—foundation loadings sufficiently distributed to permit of a light foundation structure involving, preferably, but two principal points of support. It might, of course, be possible to provide a supporting column under each of the three bearings; but with the possibility of unequal settling at the footings and temperature changes resulting from the proximity to boiler settings, it is evidently a much simpler solution of the problem to employ two points of support. At West Point only 12-in. box columns are required.

Of course it is impossible entirely to concentrate the weight of the unit on these columns. A certain proportion must be carried by the building walls. It is therefore desirable to employ a steel skeleton building, carrying the machine crane and roof truss loadings independently of the brick wall. This evidently simplifies to a large degree the problem of maintaining proper turbine alignment. Although strictly necessary only for the turbine supporting structure, the steel work may be extended upward to relieve the wall loading, with little, if any, increase in cost over that of heavier building wall otherwise necessary.

At West Point, the longitudinal members between the turbines are tied together into a continuous floor structure from wall to wall, with the sole object of reinforcement, resulting in an exceedingly rigid structure integral with the building skeleton, which has proved to be entirely devoid of any vibration. This applies also to the steel supporting columns which show no evidences of vibration.

Girder span. In the double-deck station the problem of relative arrangement of boiler and turbine capacity resolves itself into three important factors: first, number of units required; secondly, boiler grate surface for the required rate of combustion; and thirdly, cost of supporting steel work for different spans. Assuming the first fixed by the necessity of meeting a given station load curve, and the second by standard boiler practice, there remains the problem of restricting girder span over the boiler batteries. With the floor structure designed for uniform loading between supports, the weight and cost of girders will increase approximately with the span, as shown in Fig. 5, calculated.

At West Point, a rather unusual precedent has been set with the object of reducing the dimensions of these cross-members. Instead of a single girder, spanning the entire width of the battery, a row of columns has been located midway. The forward column falls in front of the boiler setting, the rear pierces the setting at the division wall, thus reducing the span to 14 ft. 7 in., and the steel work to 18 in. I-beams. This column must, of course, be artificially cooled. For this purpose, air spaces equal in depth to the column flanges have been provided on both sides, next the furnaces, to permit air circulation from below, and, in addition, cold water is circulated from top to bottom from the building service, with the result that these columns are the coldest in the plant. It is evident that any expansion or contraction would have no effect whatever upon the alignment of the turbine, this occurring midway between the turbine piers. By this unusual expedient, longitudinal girders have been entirely obviated, and the weight of these members reduced theoretically 50 per cent, an appreciable percentage of the whole building structure. In the Ft. Wayne station, 36-in. girders span the boiler batteries with 15-in. I-beams interlacing.

Boiler duty. The steam turbine is, of course, admirably adapted to meet the rapidly fluctuating and frequently excessive demands of a high-speed railway system due to a comparatively small number of cars and the universal practice of arranging interurban schedules so that a number of cars start at the same time (the even or the half hour) from important points along the line. This overload capacity of 50 per cent. or more, is readily accomplished by means of secondary admission to the turbine, and fortunately without decreasing its economy to any considerable degree. To meet these fluctuations, a corresponding forcing capacity is required in the boiler plant. Recent investigation and tests have revealed an important fact;

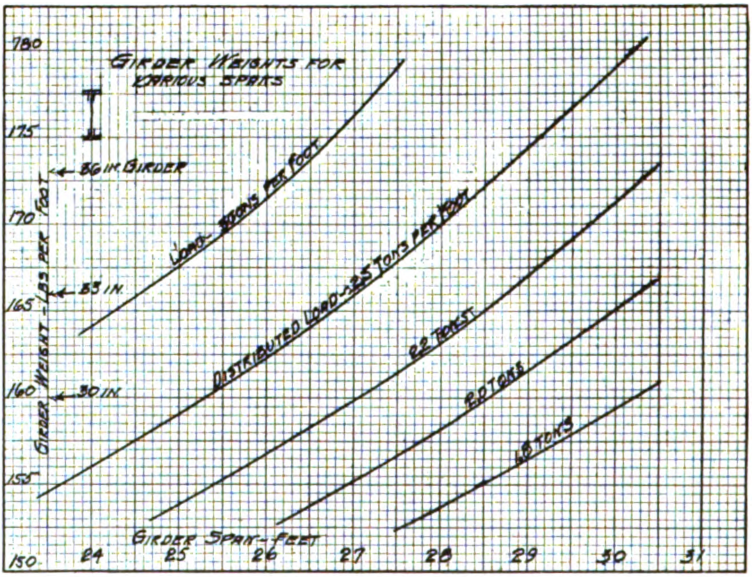


FIG. 5.—Weight of floor girders for different spans.

viz., that the steam boiler is capable of absorbing heat with very nearly the same efficiency, over a very great range of load. In other words, the boiler itself; that is, the type of heating surface, is a matter of little concern, except in detail proportions and arrangements of baffling, etc. This brings us to the furnace, which involves so many complexities, and upon which such a difference of opinion exists that it would scarcely be prudent to venture an opinion in this brief review of the subject. One thing is certain, however, that in order to avail ourselves of the forcing capacity of steam boilers, a type of furnace must be adopted in which a rate of combustion suited to the work in hand, may be efficiently maintained. For this reason, the mechanical stoker has proved an exceptionally fortunate addition to power plant equipment, insuring a range of generating capacity far beyond the possibilities of hand-firing.

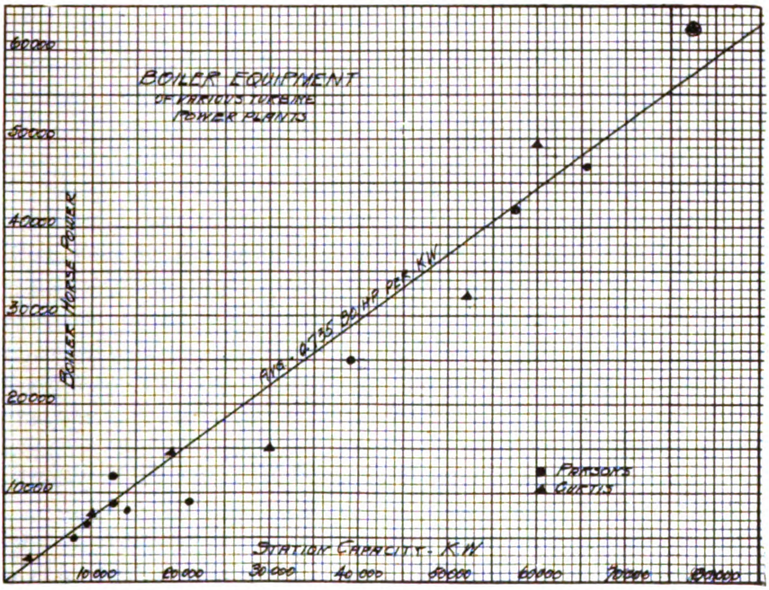


FIG. 6.—Plot representing modern practice in boiler plant equipment.

The high rate of combustion desired has been made possible chiefly by improvements in air distribution, both under the coking arch and in the grate itself. Present indications point to a combustion rate of from 20 to 25 lb. per sq. ft. per hour as a possible normal rating, whereas this formerly stood some 5 lb. lower. This performance involves one fundamental, namely, that the *effective* draft area of the furnace grate should increase with the rate of combustion—a principle quite opposed to increasing the draft pressure *alone* with the rate of combustion in order to obtain the desired quantity of air. The latter is, of course, a fundamental weakness of the hand-fired flat grate furnace, in fact any furnace in which the effective draft area is fixed. Mechanical stoking has its limitations, especially in small plants with cheap labor; but in large plants subject to severe peaks it is often imperative.

A study of modern practice in the equipment of turbine stations shows a comparatively uniform proportion between boiler and generating capacity. Eighteen modern turbine stations for railway and lighting service average close to one boiler horse power per electric horse power generating capacity, including, of course, a considerable boiler reserve.* In this connection, it is well to remember that the greater the range of boiler capacity per unit, the less the reserve necessary, the lower the investment in boiler plant, and the less space occupied. The handicap of high fixed charges to a power plant has already been called to the attention of the Institute by Messrs. Stott and Finlay. Suffice it to say that idle plant should be minimized in the double-deck station design. Several stations are below 0.75 h.p. per kilowatt. Ft. Wayne is 0.57, Yonkers and Port Morris 0.50; Carville at Newcastle, England, is only 0.44, due to liberal economizers.

Boiler construction. With one or two exceptions, boiler design has followed along well-established lines. And in the endeavor to keep pace with the great increase in capacity of prime movers, the boiler plant has increased largely in number, instead of in size of units. But to-day boiler units of 1000 to 2000 h.p. are in active demand. The limitations of the hand-fired furnace have long since been exceeded, and even those of the mechanical stoker in single units. The problem is essentially one of grate surface rather than heating surface; for this reason, the double-fired boiler has come in use. One of this type has already been described by Mr. Finlay. Another is illustrated in Fig. 8, a moderate size unit, employed extensively in a Philadelphia traction station. Quite recently an 1100 h.p. boiler unit of the semi-vertical type has been designed with double stokers and a central combustion chamber of large proportions—a very desirable feature. In the Bow Street station, Charing Cross, London, 1100 h.p. units of an English vertical type and 800 h.p. units of the horizontal type are in operation, the latter with three banks of tubes, superheater between second and third pass. These boilers are fired on three sides with flat grates at a ratio of 65 to 1. Coal is delivered from an overhead bunker to both front and side furnaces and from a point somewhat below the level of the drums, and without exceeding the critical angle, 45°. In the Interborough station, coal reaches both front and rear stokers from a central bin, without incurring an excessive angle to chutes or bends beyond that encountered in any double-deck boiler plant where chutes for the lower boilers must be carried round obstructions.

---

* Assuming one boiler out to every nine in operation, this is equivalent to an average evaporation of 22 lb. per kilowatt-hour, including steam for auxiliaries.

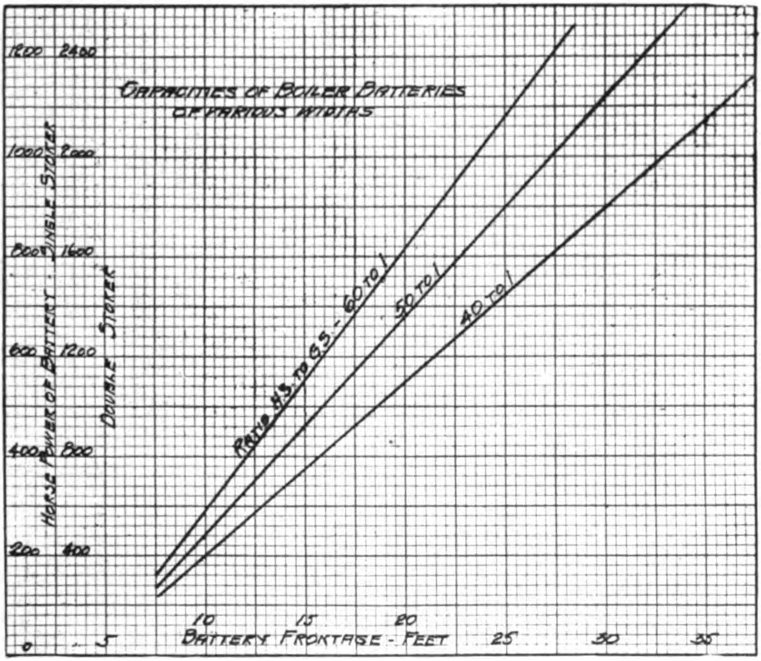


FIG. 7.—Maximum battery capacity for various widths of frontage.

In Table II the general dimensions of a number of large boiler settings are given, together with those at West Point and Ft. Wayne, for comparison. At Ft. Wayne, the stokers are served by an exterior coal bunker running along the face of the building. It is evident that any attempt to apply the double-fired boiler arrangement, would finally reduce to a question of critical angle and head room. With the height between floors

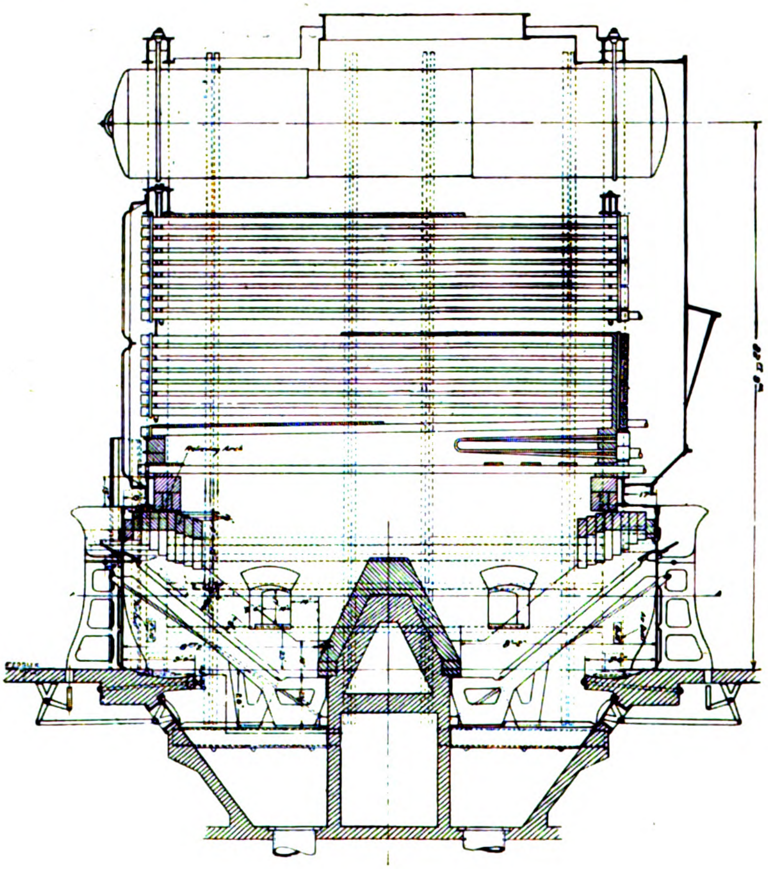


FIG. 8.

available in the larger settings, it would seem possible to reach both ends of the boilers from a single side bunker, especially with a boiler setting of moderate depth, such as is shown in Fig. 8. At West Point, the boilers are set farther back than at Ft. Wayne, in order to accommodate a coal trestle forming the storage. But with an external bunker, the settings

TABLE I.—RESUME OF CAPACITY TESTS

Water-tube boilers; inclined grate stoker; Pittsburg slack coal

No. of test	1	3	4	5	6	8	10	11	12
Duration, hours	7	6	8	6	7	8	9	9	6
Per cent. rating developed	117.2	158.0	179.1	224.7	150.3	130.0	153.0	191.0	134.6
Rate of combustion, lb. per sq. ft. per hr.	23.2	28.3	38.0	46.2	27.5	22.4	27.2	37.9	23.6
Furnace draft, in. water	0.14	0.27	0.295	0.424	0.24	0.21	0.31	0.30	0.22
Evap. lb. per sq. ft. heating temp. per hr.	4.05	5.45	6.18	7.74	5.18	4.48	5.28	6.59	4.65
Equiv. evap. (dry coal) lb.	8.77	9.80	8.23	8.50	9.41	10.20	9.70	8.70	9.86
Effcy. (dry coal) per cent.	66.8	74.0	61.8	63.4	70.4	75.0	73.0	64.0	72.2

Equipment: Inclined header water tube boiler, 3750 sq. ft.=375 h.p. Mechanical stoker, ratio heating to grate surface, 49 to 1, natural draft.

TABLE II.—DATA ON LARGE BOILER SETTINGS

Name of Boiler and stoker	B. & W. Roney	Parker Roney	Stirling Roney	Hornsby Hand	Hornsby Hand	Stirling Hand	B. & W. Roney
Location	Interboro, 59th St., New York	P. R. T. Phila.		Charing Cross London	Charing Cross London	West Point, Ohio	Ft. Wayne, Indiana
General type	Horiz. No Sup.	Horiz. Supht.	Vert. Supht.	Vert. Supht.	Horiz. Supht.	Vert. No Supht.	Horiz. Supht.
Where fired	Both ends	Both ends	Both ends	Sides and front	Sides and front	Front	Front
Boiler h.p. per battery (10 sq. ft.)	1200	1600	2200	2170	1620	800	800
Ratio grate to heating surface	30	49	53.5	64.5	65	50	48.3
Area required (sq. ft. per b.h.p.)	0.56	0.363	0.352	0.464	0.445	0.59	0.69
Frontage of setting at floor	31 ft. 0 in.	25 ft. 4 in.	31 ft. 0 in.	37 ft. 6 in.	25 ft. 8 in.	28 ft. 0 in.	25 ft. 0 in.
Depth of setting at floor	22 ft. 1 in.	22 ft. 10 in.	25 ft. 0 in.	27 ft. 0 in.	28 ft. 0 in.	16 ft. 9 in.	22 ft. 1 in.
Height to center-line of drums	19 ft. 0 in.	22 ft. 9 in.	31 ft. 3 in.	28 ft. 0 in.	27 ft. 5 in.	20 ft. 0 in.	15 ft. 3 in.
Height to top setting	22 ft. 3 in.	26 ft. 9 in.	34 ft. 0 in.	——	——	22 ft. 6 in.	17 ft. 3 in.
Height between floors	——	——	47 ft. 2 in.	——	——	33 ft. 0 in.	28 ft. 5 in.

could be located well forward with arches in the building wall communicating with the room under the bunkers. Furthermore, it would seem possible to make use of the space above the coal bunker for a switch room, as it would be approximately at the proper level.* This rearrangement permits of sufficient space in the rear of the boilers for flues overhead and pumps beneath.

In order to indicate in a general way the possibilities of the large boiler units, the author has prepared a diagram showing the maximum stoker grate area that may be installed in batteries of two boilers each, with varying spans between turbine piers, presupposing, of course, that the proper heating surface may be obtained by extending the boiler upward, whether in the vertical type or with an extra bank of horizontal tubes. Thus with a ratio of 50 to 1, a frontage of 30 ft. will accommodate 2240 boiler h.p. maximum, sufficient to serve a 3000 kw. turbine. This is approximated in the 2200 h.p. battery noted in Table II, which is 31 ft. over all.

Condensers. The West Point station is an excellent example of the possibilities of a compact condensing plant. The barometric condensers are attached directly to the turbine exhaust. Here the condensers are arranged in line with the boiler fronts, but with a passage of over 6 ft. between boiler settings, it is quite evident that the condenser may be placed wherever most convenient, irrespective of the position of the batteries, and with a discharge tunnel conveniently located.

It seems almost superfluous to emphasize the advantages of a short and direct connection to the condenser which obviates both the friction of bends and the bulk of large exhaust piping. The suspension at West Point permits of an atmospheric relief connection between the supporting girders, resulting in a distance of only about 2.5 ft. from the floor level to the condenser head. Here the barometric condenser and horizontal turbine are evidently at their best advantage, both as regards compactness and efficiency—an arrangement which cannot be duplicated by any other type of apparatus.

---

* In fact boiler fronts might be advanced to the building line, omitting the brick wall entirely from floor to roof, excepting the side wall of the bunker, leaving only the steel columns with a 6-ft. gallery overhanging the turbine room. Switchboards might then be located as at West Point, in line with the steel work, with all control and protective apparatus behind.

The degree of vacuum desirable appears to be a matter of opinion. With a turbine that is not unduly sensitive to vacuum, it would seem unwise to incur the additional complexity of extremely high vacuum apparatus. Indeed, for the majority of inland plants, the high temperature of circulating water available during the summer months would render of no avail the condenser plant designed for higher than 28 in. vacuum. The general preference seems to indicate a moderate vacuum of 27 to 28 in., and several condenser manufacturers are now manufacturing barometric condensers to maintain this vacuum without the use of auxiliary dry air pumps. Taking into account the three or four per cent. gain per inch of vacuum, it is indeed questionable whether it would pay to incur the additional cost and complexity of operation with comparatively cheap coal found in the middle West. But this is always an individual engineering problem. To give some idea of the limitations of cooling water temperature, it is sufficient to note that with a ratio of 60 of water to 1 of steam, and a condenser working to within 15° of the exhaust temperature, the maximum possible vacuum will be 28 in. with 70° and only 27.4 in. with 80° water, not an excessive temperature for midsummer.

Auxiliary plant. The Ft. Wayne station employs direct-driven exciters at the end of the turbine shaft, each of sufficient capacity to operate two machines. These direct-connected exciters add 2.6 per cent. to the cost of the main unit, but as compared with the cost of an equivalent independent exciting plant, including reserve, they show some 20 per cent. in favor of direct drive. This subdivision evidently assures uninterrupted service to a degree almost equivalent to the standby storage battery, for with half the exciters inoperative there would still be ample capacity remaining.

On the other hand, the same degree of voltage regulation cannot be obtained except with automatic voltage regulators and the exhaust steam of exciters such as are used at West Point, is unavailable for feed heating. In spite of this, a feed temperature of 160° to 180° is obtained at Ft. Wayne, and even 200° at peak loads.

The high-speed centrifugal pump for condenser injection works well into the scheme at West Point, and with syphon or other means for priming is admirably adapted to the moderate head to be pumped against. Moreover it is considerably more compact and delivers a constant injection, which cannot be said of the long stroke, slow-speed reciprocating pump unless an air chamber of ample proportions be provided to prevent "dip" in vacuum to tide over dead center. As entrained air is the greatest deterrent to high vacuum, it is important to submerge the intake well below surface water, as at West Point, to avoid the aeration existing at the surface of the intake crib.

The question of auxiliary drive is important. Recently it developed during a test that a 1000 kw., well equipped turbine station was using on the average nearly 24 per cent. of the total steam in auxiliaries. A common figure is 10 to 12 per cent. for plants of 1000 to 2000 kw. Hence the necessity of moderately economical auxiliaries. At one turbine station in Philadelphia the condenser discharge pump is driven by a belt from the turbine shaft. This, however, would not be applicable in the double-deck station. At Newcastle, England, all auxiliaries are motor-driven, economizers being used to heat the feed water. It is evidently a nice engineering problem to find a happy medium between excessively wasteful auxiliaries, and low feed temperatures.

Ventilation. In the double-deck station it is important to draw ventilating air from the outside to avoid not only the heat above the boilers, but also the possibility of escaping steam reaching the generator insulation. Some little difficulty here arises in avoiding structural work, but hardly to any greater degree than in the ordinary station. At West Point one vertical and one horizontal offset to the ventilating ducts suffice to clear both columns and girders. At Ft. Wayne a rectangular steel duct extends from one end of the building to the other in front of the boilers, drawing air from either end, according to the prevailing winds. Each generator then draws from this air header through comparatively short and direct connections. An auxiliary steam-driven blower in the adjoining area way has also been installed to assist in delivering more air to the generators during very hot weather and peak loads. With this provision against excessive temperature rises in the generators, even under the worst conditions of atmosphere and load, there follows the maximum security against interruptions and the possibility of tiding over emergencies.

Piping. The avoidance of long runs and bends in steam piping is, of course, fully as important, if not more so, than in exhaust piping, and with boilers beneath turbines a most simple and desirable arrangement is possible. In the Ft. Wayne station the steam has but 30 to 35 ft. to travel between any turbine throttle and the boilers supplying this particular machine, and with only two long-sweep bends intervening. Moreover, piping may be most readily drained—a point of value, even with superheat. At Ft. Wayne, there is a continuous slope to the boilers. At West Point where no superheaters are used, the header is drained by steam traps, separators being provided in each turbine line as an additional precaution.

Under normal working conditions, therefore, the plant operates almost entirely on the unit system, with the interconnected header properly sectioned to isolate trouble in emergencies. In both stations each turbine line connects to the header close to the feeders from the boilers supplying it, so that the header operates simply as an equalizer between the various points of demand. Owing to the directness of the piping, comparatively high steam velocities and small pipe sizes may be employed, thus reducing radiation without serious drop in pressure. The great simplicity of this piping arrangement is well attested by the fact that at Ft. Wayne the cost, complete, from boiler nozzle to turbine throttle, was only $2.50 per kilowatt.

Switch room. There is an excellent building arrangement at West Point to provide for switch room and auxiliaries. An addition to the rear of the main building accommodates the electrical apparatus above, and the feed pumps, circulating pumps, and heater below. This addition provides a rectangular engine and boiler room of minimum proportions, with centralized auxiliary and electrical control plants, permitting the installation of the switchboard in a most convenient position between the building columns, with all the high-tension apparatus in the rear, including high-tension bus-bars, circuit-breakers, and protective apparatus with transmission line outlets near the roof. In the 33 ft. between floors, there is space for a mezzanine floor or gallery for some of the small auxiliaries, but this has not been made use of at West Point. To be sure an elevated switchboard might have been used as at Ft. Wayne, but the extra room required for heaters and auxiliaries, would necessarily have been provided in the main building at the cost of extra ground floor space.

Summary. I have touched briefly upon certain features of the double-deck type power station, which constitutes the most important factors in working out a successful design. Inasmuch as many of the refinements of modern power stations are absent, the highest operating efficiency could scarcely be looked for, and in the three stations already built simplicity has perhaps been the controlling factor, leading to minimum labor cost. On the other hand, non-indulgence in refinement has greatly reduced the first cost of the complete station. Incidentally, lower fixed charges are incurred against operation, also a somewhat lower rate of depreciation. The general result is a tendency to make the total cost of operation lower than in a more efficient plant with correspondingly high investment.

The Ft. Wayne station is an excellent example of this principle. Based upon the present cost, the power station when completed—8500 kw. in capacity—will have cost $66.25 per kw. exclusive of all sub-station apparatus, property, and siding. For the present uncompleted plant, the cost per kilowatt is, of course, higher—around $75 per kilowatt, including sub-station equipment. To show the distributed cost, Table III is quoted from a former paper. To many, these costs will appear exceptionally low, but they are correct as far as it is possible to segregate the various items from the numerous vouchers. This at least will serve to show the tendency toward low station costs, resulting from simplicity of design. In smaller stations,

TABLE III.

COST OF COMPLETED POWER STATION, 8500 KW., NO SUB-STATION APPARATUS.

	$	$ per kw.
Building: Including general concrete and steel work, coal bunker, smoke flue, condenser pit, coal storage pit, etc	93,217	10.97
Generating plant: Including turbines, generators, exciters, cables, switchboards, transformers, and ventilating ducts	259,711	30.55
Boiler plant: Including boilers, superheaters, stokers, piping, pumps, heaters, settings, breechings, and tank	118,313	13.92
Condenser plant: Including condensers, pumps, piping, free exhausts, water tunnels, and intake screen	33,790	3.98
Coal handling plant: Including gantry crane, crusher motors and track	7,990	0.94
Erection, superintendence and engineering	50,500	5.94
Total, excluding property and siding	563,520	66.25

like that at West Point, such low cost would not, of course, be expected; in larger ones it should be exceeded.

The price of coal and labor is in all cases a controling factor. With cheap coal, high vacuum and superheat, high-efficiency auxiliaries and economizers are evidently non-essential. But with coal above $3.00, and with city labor, conditions might at least justify the use of superheaters, and amplified condensing plant, with rotative dry-air pumps. The internal type superheater is now a simple and durable apparatus for moderate temperatures when protected by sufficient steaming surface; that is, installed between first and second pass of tubes. There is at present a tendency in boiler practice toward the addition of so-called economizer surface to the boilers themselves, rather than in the form of external economizers.

For the average power plant, the more moderate conditions of operation appear to be in favor-- 150 to 175 lb. pressure, 75° to 125° superheat, and 27 to 28 in. vacuum. The examples we have studied show that an extremely simple plant design embodying these features, is possible. That future development will result in still further improvement, goes without saying. Much credit is due the designers of these present stations for their courage and initiative in testing out the possibilities of the double-deck type.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29–July 2, 1908.

Copyright 1908. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

WORKING RESULTS FROM GAS-ELECTRIC POWER PLANT

REPORT OF 30-DAY TEST ON SERVICE PLANT, RICHMOND WORKS AMERICAN LOCOMOTIVE CO., RICHMOND, VA.

BY J. R. BIBBINS

In this paper an attempt is made to present a general study of a problem upon which only very limited data seem to be available—power generation by gas-engine-driven plants, its commercial efficiency, and ultimate cost. I think it best to approach the subject from the operating standpoint, basing calculations upon actual working results from a specific case, one of demonstrated fact. The Richmond tests* are conclusive in this respect, and although somewhat limited in scope (being only a commercial test), nevertheless provide a starting point for further deductions. While of a somewhat cursory nature, it is hoped the data presented will serve at least to emphasize the wide field of the modern gas power plant.

The Richmond plant. The equipment consists of a 23.5 by 33, horizontal, tandem gas engine, with a direct connected direct-current generator, operating on producer gas generated by a pair of 9-ft. (shells) bituminous producers. The gas is purified by means of wooden slat scrubbers and centrifugal tar extractor, motor-driven. A 15,000 cu. ft. holder serves to equalize its quality and to start the engine, which is necessary to bring the motor-driven auxiliaries into service. The engine is of the modern double-acting type, giving two impulses per revolution, and is governed by a sensitive oil relay system designed to relieve the governor of all valve work. Employing the constant quality method, the ratio of air to gas is constant except when the gas itself changes, for which event hand-regulating dampers are provided. Duplicate igniters work together for increased security. For the same reason duplicate sources of igniter current are available—motor-generator and lighting mains. An important feature of the producer is that it is designed for continuous operation, having a water-sealed bottom instead of a closed ash pit, to permit the removal of ash at any time. It generates its own steam, requiring no auxiliary boilers, so that the only auxiliaries required for the entire plant are a motor-driven fan, tar-extractor, and igniter set. In the aggregate these auxiliaries absorb about 5 per cent. of the station capacity.

---

*Presented by courtesy of Mr. Wm. Dalton, chief engineer. American Locomotive Co.

The Richmond works employ motor-drives to a considerable extent, and for such diversified purposes that the individual demands superpose to a large degree and yield a fairly constant total. This is a condition conducive to the most efficient working of a gas power plant, and influenced to some extent the choice of this form of motive power in this particular location. Constituting the main service plant of the Richmond works, it is called upon for continuous 24-hour service, except on Sundays and holidays.

Herein lies one essential requirement for a producer plant test. Owing to the comparatively long period required for a pound of fresh coal to work through a fuel bed several feet deep, a long test is necessary for any degree of accuracy. With the rapid combustion on a boiler grate, this is a different matter, and an 8- or 10-hour test will suffice. But in producer work, 24 hours, or 48 hours, is the minimum. In this case, the test was continued for practically four weeks, half of the time on a full load run and the remaining two weeks to three-fourths and one-half load respectively, with a rate of gasification of 0.25 tons per hour. A continuous run of 223 hours' duration evidently provides an excellent guarantee of accurate results.

The test. From the great mass of data recorded during this test, it will suffice to extract only such as pertain to the operation of a plant of this nature. The test was conducted entirely by the company's engineering and operating staff, and for the purpose of determining the fulfilment of guarantees. The electrical output was measured by direct-current recording wattmeters calibrated from a laboratory standard previous to the test. The water consumption was also metered, no great accuracy being desired. The coal was weighed by scales checked from time to time by standard weights.

Samples from such weighings, accumulated during a day's run, were quartered down and sealed for analysis, Table I.

It should be noted that at full load, 312 kw., the engine was running somewhat below full rating, but the true full-load coal consumption may readily be found. For this purpose, these data have been plotted in Fig. 1 in the form of three related curves: (a) Rate of gasification in pounds per hour; (b) Pounds per unit of output per hour, and (c) Corresponding thermal efficiency. The first mentioned curve is important in all analyses of steam or gas engines to determine the rationality of the results, for the line of heat input to the engine as well as to the producer should be practically straight, as developed during the test of a similar engine at the works of The Norton Company.* The second curve, showing the relative fuel

TABLE I.

GENERAL RESULTS OF TEST.

Nominal Load	Full	Three-Quarters	One-Half
Length of run, hours	223	125	136
Average load, kw	312.3	228.3	159.6
Average load, computed boiler h.p.	455.0	333.0	238.0
Load, per cent. engine rating	91.0	67.6	47.5
Load, per cent. generator rating	104.0	77.2	53.2
Coal gasified, lbs	115,289	54,143	47,775
Coal gasified per hr	517.0	433.0	351.0
Output, kw-hr	69,650	28,540	21,710
Lbs. coal per kw-hr	1.654	1.697	2.20
Lbs. coal per kw-hr., guaranteed	1.93	2.10	2.64
Lbs. coal per boiler h.p-hr	1.14	1.31	1.56
Avg. heat value of coal, B.t.u	14,392	14,392	14,392
B.t.u. per kw-hr	23,700	27,280	31,650
B.t.u. per boiler h.p-hr	16,415	18,710	21,670
Per cent. thermal efficiency, brake	15.51	13.6	11.75
Per cent. thermal efficiency, elec	14.35	12.65	10.78

Coal.—Pocohontas Run-of-mine; avg. heat value dry sample, 14,703, as fired, 14,392; volatile matter, 22.8%, ash 4.5%, sulphur 1%.

Test.—August 12, 7 a.m., to September 7, 12 m.

---

* A. S. M. E., December, 1907.

economy at variable loads, necessarily follows the form of an equilateral hyperbola, being derived from the line of total coal input. Finally, the third curve, efficiency, represents that part of the heat in the coal that has been converted into useful work. This is absolute or kinetic efficiency, and not akin to the "efficiency ratio" employed in steam-engine practice. It covers all losses between coal pile and switchboard.† It is found that the gross coal consumption of the plant at full engine load, is 550 lb. per hr., or 1.59 lb. per kw-hr., equivalent to approximately 1.09 lb. per boiler h.p-hr. And with 400-kw.

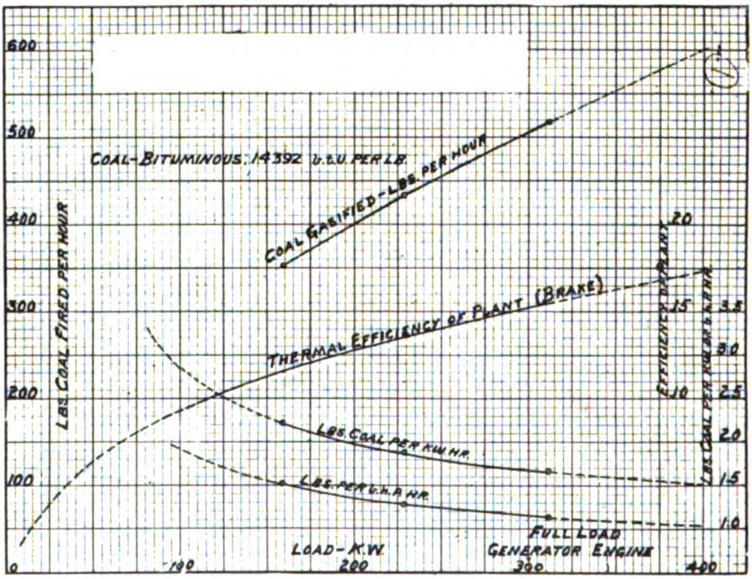


FIG. 1.—Gas power plant economy at various loads.

load, which is easily within the limits of this particular plant, the coal consumption would be roughly 1.5 lb. per kw-hr., or 1.0 per boiler h.p-hr.

This characteristic of constantly increasing economy shown by the gas engine plant up to the point of maximum load illustrates an essential difference from steam engine economy which usually is best at loads 70 to 80 per cent. rating, according to the cylinder ratios employed. Although the gas economy curve is quite flat beyond half-load, yet the plant evidently does its best work well loaded. By projecting backward the line of total coal gasified, we find that it requires over one-third of the full-load coal to run the plant unloaded. This represents a standing charge against its operation, becoming less and less important as the load increases. Barring this constant loss, this plant would be capable of generating power at the rate of one pound of coal per kilowatt-hour, which rate would, moreover, be *constant at all loads*. In other words, additional load might be acquired at this rate by providing for the constant losses as a fixed charge. This method is actually employed by some central stations in determining power rates.

---

† Taking the mechanical equivalent of heat as 776 B.t.u., the thermal value of one horse power is 2545 B.t.u., or of a kilowatt, 3412 B.t.u. Hence, absolute thermal efficiency equals 2545 per B.t.u. per b.h.p., per hour, or upon an electrical basis, 3412 per B.t.u. per kw-hr.

During the four weeks' test, there were several days during which the plant was allowed to stand idle, as the works are not operated Sundays. During this period, some coal was required to keep the producer fires at their normal level and in good condition. It would, of course, have been possible to starve the fires during standby periods, but this would simply have resulted in a higher coal consumption during the succeeding run. According to the judgment of the producer operator, an average of 1700 lb. of coal were required to compensate for standby losses from 6 p.m. Saturday until 7 a.m. Monday, a period of 37 hours. Herein lies a remarkable feature of the producer plant—the low rate of standby losses, averaging only 46 lb. per hour, or 2.5 per cent. of the weekly coal consumption.

Carrying this analysis one step further, Fig. 2 shows a graphical method of determining the producer plant efficiency. Here are plotted three economy tests and the standby loss. Not knowing the heat input to the engine at various loads by actual test, the guaranteed efficiencies have been plotted extending the line backward to a point of zero input. This corresponds to 166 kw. total losses in the engine unit. Assuming that the producer is maintained ready for operation, there are four points to determine the curve or line of producer input. And the ratio between engine and plant output gives directly the gross efficiency of the gas generating plant from coal pile to engine throttle. This curve shows that the producer maintains remarkably uniform efficiency throughout the range of plant load. This results from the fact that at zero output of station the producer is operating at over one-third its full-load rate.

A careful measure of oil consumption was made during the two weeks' run at full load, comprising 223 hours' operation, also the water consumption of the engine. During this period, the average rate of cylinder oil consumption was 0.09 gal. per hour, or, on the basis of a ten-hour working day, 4.9 gal. per week. This confirms to a considerable degree, the experience at the Norton works, where an engine of the same size uses 3.5 to 4 gal. per week, ten-hour day—a rate so low as to have excited suspicion of its correctness. The high economy of oil is, however, due to the system of timed, forced circulation employed.

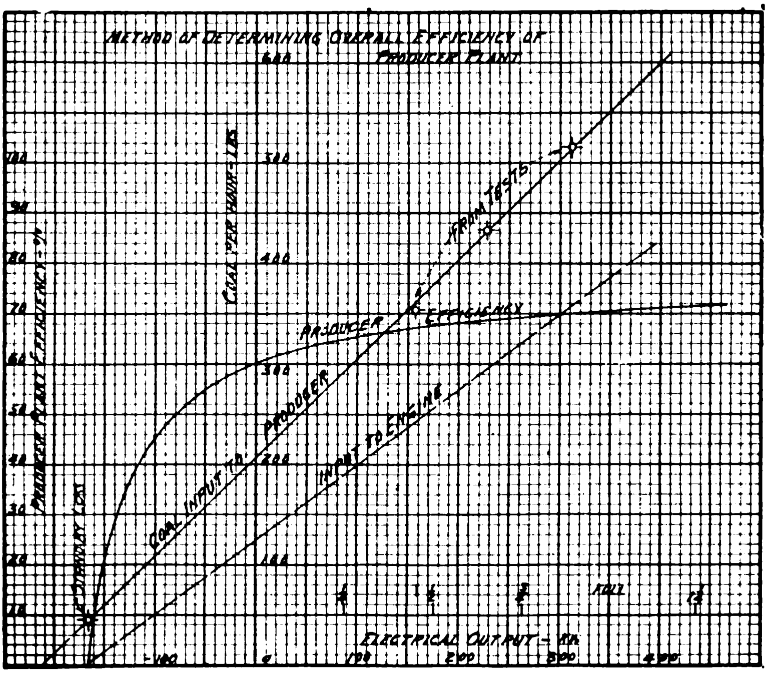


FIG. 2.—Graphical method of determining over-all efficiency of producer plant.

The average quantity of cooling water used was 6.56 gal. per boiler h.p-hr. at heavy load with inlet temperature varying from 75 to 80° fahr. and outlet from 140 to 150° fahr. This quantity is quite reasonable for the temperature rise. Inasmuch as a definite quantity of heat must be removed from the engine at a given load, the volume of water necessary evidently varies with the rise, so that in winter even less cooling water would be required. Economy of water may be carried to any reasonable point provided the outlet temperature of any part does not exceed 150° fahr. The upper limit only is important.

Operating results. It seems to be the general impression that a gas-power plant must be handled gingerly in order to obtain good results. The accompanying operating data from Richmond should dispel this impression. Fig. 3 shows typical results for two months' operation, representing, if anything, an output somewhat below normal. It is worth while to note the continuous operation throughout the week, 24 hours per day, and particularly the high average load sustained. The normal run at Richmond is six days without stopping. In fact the producer fires remained undisturbed from July 4, 1907, until early in the present year, when an opportunity occurred to make careful inspection of the entire equipment.

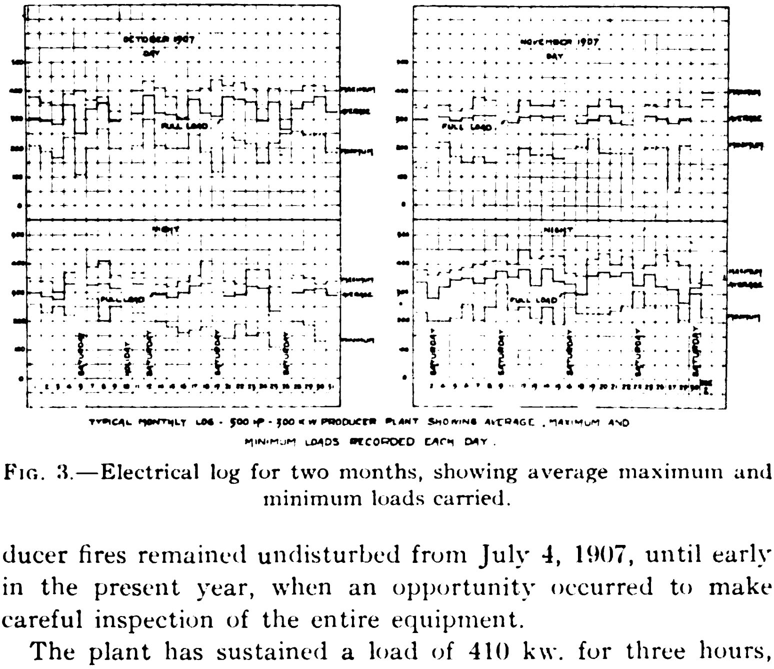


FIG. 3.—Electrical log for two months, showing average maximum and minimum loads carried.

The plant has sustained a load of 410 kw. for three hours, 19 per cent. overload on the engines, and even higher overloads for short periods. With rich gas, the power of the engine is correspondingly increased in a manner exactly analogous to the effect of variation in boiler pressure in a steam plant. How far this conservative practice may be carried depends upon the operator; it is for him to decide the limitations of his plant.

Operating costs. From the preceding data and the other items of cost, the cost of power may be estimated at various load-factors. Owing to the fact that the present power plant was

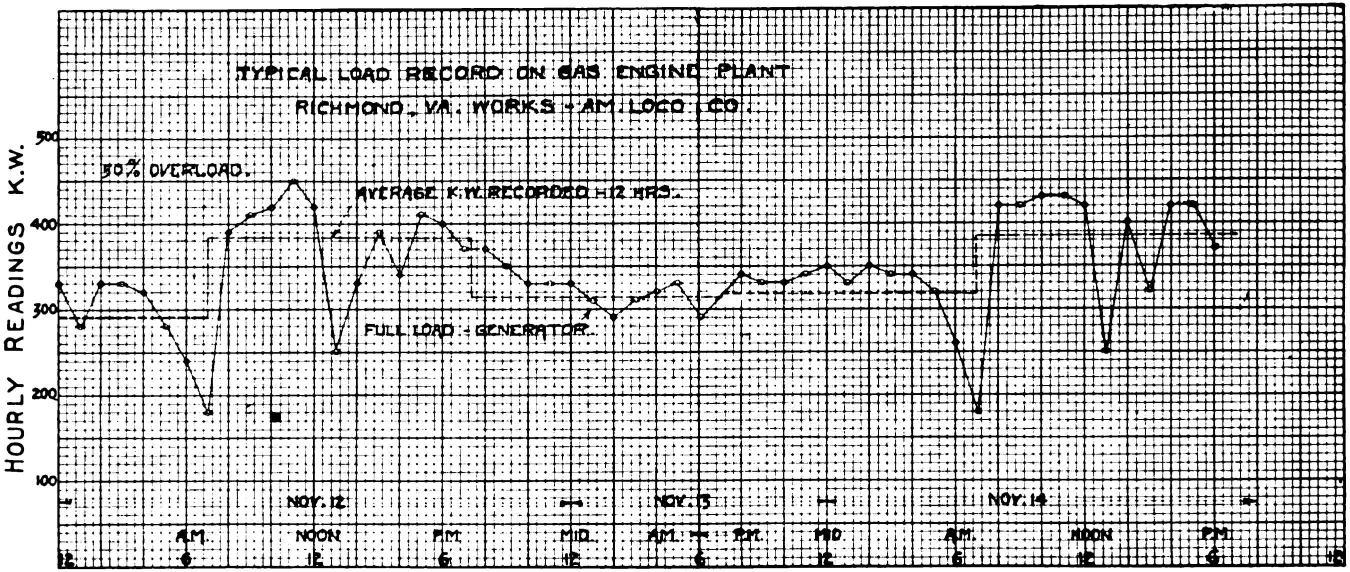


FIG. 3A.—Typical hourly load record, showing overload capacity of plant.

made to accommodate a two-unit plant, the cost has been computed upon this basis; and in view of the excellent results that have been obtained the electrical rating of the plant has been placed at 700 kw., or 1000 h.p., at which rating the investment cost becomes about $138 per kw., or $96 per boiler h.p. complete, including machinery, buildings, foundation, piping, erection—in fact all items except the value of the land occupied. Considering the limited size of the plant, this does not represent an excessive cost, which in large plants would probably be as low as $100 to $125 per kw.

TABLE II.

COST OF POWER, 700 KW. GAS POWER PLANT.

ASSUMPTIONS.

Equipment cost:	
Building and machinery	$96.60
Cost per kilowatt, $138, per boiler h.p., $96.60.	
Fixed charges:	
Interest 5%, taxes and insurance 1.5%, depreciation (sinking fund 15 years 5%), 4.63%, running repairs 1.5% on investment. Total 12.63% per year	12,220
Operation:	
300 days, 7200 hr. per year, 5,040,000 kw-hr.	
Input to auxiliaries, 5.4% full, 10.8% half-load.	
Standby losses, producer plant, 1600 lb. per week, 2.1% full, 3.1% half-load.	
Fuel rate, full load, 1.59 lb. + 2.1% = 1.62 lb. per kw-hr.; ½-load 2.1 lb. + 3.1% = 2.17 lb. per kw-hr.	

COST OF POWER, 700-KW. TURBINE PLANT.

ASSUMPTIONS.

Equipment:	
Building and machinery, $100 per kilowatt	$70,000
Fixed charges:	
Interest 5%, taxes and insurance 1.5%; depreciation (sinking fund 16⅔ yrs. at 5%) 4%; repairs 1%; total 11.5%	8,050
Operation:	
300-day year, 7200 hr.	
Average water rate, full-load 21.5 lb. per kw-hr.	
Average water rate, one-half load 25.5 lb. per kw-hr.	
Gross evaporation, 7.5 to 8.0 lb.	
Standby, banking, 10 to 15%.	
Gross coal consumption, full, 2.96 lb. per kw-hr.; half, 3.9 lb. per kw-hr.	
Wages and supplies—Same as gas.	

In this total cost of power are included the usual fixed charges —interest at 5 per cent., taxes and insurance 1.5 per cent. In the absence of any data on repairs (there having been none on the engine up to the present time, and very small repairs on generator and producer), this item has for convenience been included in the fixed charges at 1.5 per cent. on the plant investment. Further, depreciation has been included in the form of a sinking fund, based upon 15 years' life of plant at 5 per cent. interest. This latter method may be contrary to general practice, but considering the nature of the depreciation fund and its earning capacity, the annuity method seems most logical.

TABLE III.

COST PER KILOWATT-HOUR AND HORSE-POWER-YEAR, GAS PLANT.

Cost items		Full load	Half load
		Cents per kw-hr.	
Coal	at $1.00	0.081	0.109
	2.00	0.162	0.217
	4.00	0.324	0.434
	6.00	0.486	0.651
Wages	per year, $6,160	0.121	0.242
Supplies	" 3,850	0.076	0.143
Fixed charges	" 12,200	0.242	0.484
Total costs—coal at $1.00		0.520	0.978
2.00		0.601	1.086
Richmond coal....2.70		0.658	1.163
4.00		0.763	1.303
6.00		0.925	1.520
		Dollars per electric h.p. year	
Equivalent power rate:			
300-day year, coal at $1.00		$27.90	$52.40
2.00		32.30	58.20
2.70		35.60	62.40
4.00		41.00	69.90
6.00		49.60	81.50
Charges for auxiliaries if motor-driven		2.7%	7.4%
Saving gas over steam:			
Coal at	1.00	—3% loss	—8.5% loss
	2.00	+8% gain	+0.9% gain
	2.70	12.9% "	4.7% "
	4.00	19.6% "	12.4% "
	6.00	33.7% "	19.0% "

These costs are shown in Table III. Based on 300-day operation, 7200 hours per year, the fixed costs are distributed only over the operating period, not over the entire year. And, assuming the price of coal largely determined by location, the efficiencies at various loads are considered constant, irrespective of the price of coal. Both standby losses and power consumption charges have been included. As we are considering an industrial plant in which the load averages practically uniform throughout the day, it suffices to estimate power costs at full and half loads respectively. This has been done in Table III for various coal prices. Coal prices are based upon net ton.

The results show that at the price of fuel at Richmond, $2.70, power can be delivered at switchboard at a cost of two-thirds of a cent per kilowatt-hour for a fully loaded plant operating 7200 hours per year, or less than 1.25 cents operating at half-load, and this taking into account fixed charges which range around 40 per cent. of the total cost. Even with coal as high as $6 per ton, the total cost of power would be under one cent per kilowatt-hour, obviously an excellent result.

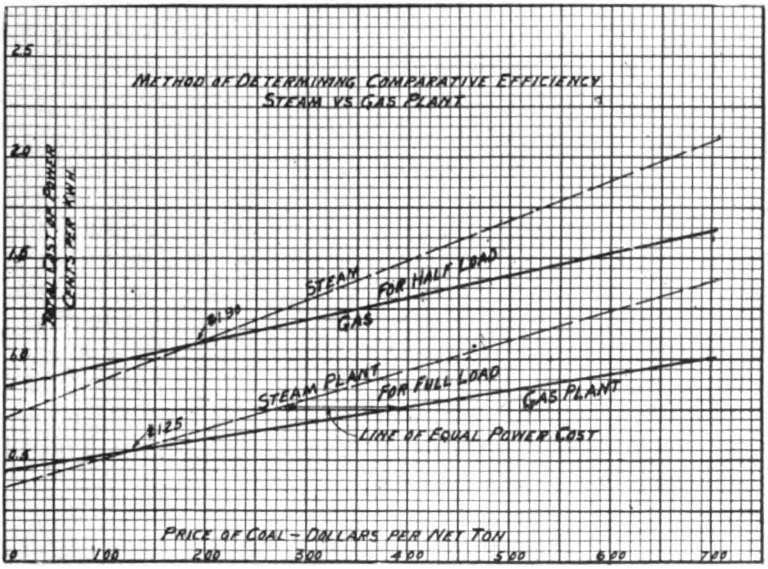


FIG. 4.—Graphical method of determining comparative cost efficiency, producer gas versus steam turbine plant for Richmond conditions.

Relative cost of gas and steam power. That there may be no misunderstanding of the preceding cost results, a comparison has been drawn up for a steam turbine plant operating under the same load. This comparison covers only two variable factors, coal cost and loading. And, while not intended to be of more than tentative interest, it will serve to show the general range of working in which the gas and the turbine plant will respectively predominate. The assumptions upon which this comparison is based, are given in Table II, the costs are embodied in Fig. 4, and the relative saving in Table III.

At the price of coal prevailing in Richmond, the gas plant shows 13 per cent. gain over steam at full load, and 5 per cent. at half load. Owing to the handicap of higher fixed charges, the turbine plant naturally shows a lower power cost with low-priced coal; that is, where freight rates are low. But even a mine operator is not justified in charging himself for power fuel less than the prevailing market price (f.o.b. mines). For the high-grade fuels, the mine rates are about $1.25 for run-of-mine and $0.90 for slack and screenings. Hence, in reality, this gas power system influences an extensive field. It is evident from the diagram that a less efficient prime mover than the steam turbine would show a cost-line lying not only above but at a greater inclination than the turbine line, which would bring the point of equal cost between gas and steam to a still lower price of coal, and largely increase the saving. In Fig. 4 the crossing of the steam and gas lines indicates the starting point of gas power work—$1.25 coal for a fully loaded plant, and $1.90 at half-load. Or, considering the matter in another light, with steam coal at $2.70, we could afford to pay about $4 for gas coal for the same cost of power.

On the other hand, with light loads or fluctuating loads averaging but a fraction of the generating capacity, the gas plant is evidently at a disadvantage. And for this reason the turbine plant still finds exclusive application in all service subject to extreme overloads of variations. In fact, with the extension of a large electric power system, such as at the Richmond works, it is possible that a combined gas-engine-turbine plant may best meet load requirements with the highest resultant economy, the turbine unit carrying fluctuating peaks and the gas engines the uniform load, as suggested by Mr. H. G. Stott. At present, hot gas-engine jacket-water is utilized directly for boiler feed in an auxiliary air-compressing plant, although charged for in the cost table. This arrangement would, of course, be even more applicable to the combined plant, permitting most of the auxiliaries to be motor-driven without loss of heat for feed water.

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29–July 2, 1908.

Copyright 1908. By A. I. E. E.

(Subject to final revision for the Transactions.)

WIRELESS TELEPHONY

BY R. A. FESSENDEN

SYNOPSIS

A. Preface.

B. Brief history of the development of wireless signaling.

1. Introduction.
2. Period 1838–1897. Origin and development of old or damped wave-coherer method.
3. 1898. Return to first principles and foundation, on lines antithetical to old, of new or sustained oscillation-non-microphonic receiver method.
4. Fundamental differences between the old and new wireless schools.
5. Period 1898–1902.
    - (a) Development and perfecting of sustained oscillation-non-microphonic receiver method.
    - (b) Further development of damped wave-coherer method.

General abandonment of old method and adoption of new method.

6. Period 1902–1908. Later developments.

C. Theory of wireless telephony.

D. History of development of wireless telephony.

E. Method and apparatus.

F. Operation.

G. Possibilities.

H. How wireless development has been prevented by governmental action.

I. Considerations.

K. Appendix.

A. PREFACE

The discussion of the theory, practical operation, and possibilities of wireless telephony is facilitated by first briefly considering the history of the development of wireless signaling generally.

B. BRIEF HISTORY OF THE DEVELOPMENT OF WIRELESS SIGNALING

1. *Introduction.* In preparing this note it has been considered best, for the sake of accuracy, to refer to published results, such as scientific articles or theses or patent specifications. For the sake of brevity, references to work done in repetition of previously published work has as a rule been omitted. So far as possible, the expression of personal opinion has been avoided in this section of the paper, the object being to gather together in concise form the facts known in regard to the development of the art. With the exception of Munk's original paper, which could not be obtained, all references have been verified by consulting the original publications, a work of some labor, and if any omissions or mistakes have been made data for their correction will be much appreciated.

2. *Period* 1838-1897. *Origin and Development of Old or Damped Wave-coherer Method.* Joseph Henry, to whose work the development of wire telegraphy owes so much, was the first (1838-1842) to produce high frequency electrical oscillations, and to point out and experimentally demonstrate the fact that the discharge of a condenser is under certain conditions oscillatory, or, as he puts it, consists "of a principal discharge in one direction and then several reflex actions backward and forward, each more feeble than the preceding until equilibrium is attained".[1]

This view was also later adopted by Helmholz[2] but the mathematical demonstration of the fact was first given by Lord Kelvin in his paper on "Transient Electric Currents".[3]

In 1870 Van Bezold discovered and experimentally demonstrated the fact that the advancing and reflected oscillations produced in conductors by a condenser discharge gave rise to interference phenomena.[4]

---

[1] Scientific Writings of Joseph Henry, Smithsonian Institution.

[2] Helmholz "Erhaltung der Kraft", Berlin, 1847.

[3] Kelvin, *Philosophical Magazine*, June, 1853.

[4] Van Bezold, *Poggendorff's Annalen*, 140, p. 541.

In 1883 Professor Fitzgerald suggested at a British Association meeting[1] that electromagnetic waves could be generated by the discharge of a condenser, but the suggestion was not followed up, possibly because no means was known for detecting the waves.

Hertz[2] discovered a method of detecting such waves by means of a minute spark-gap and before March 30, 1888, had concluded his remarkable series of researches in which for the first time electromagnetic waves were actually produced by a spark-gap and radiating conductor and received and detected at a distance by a tuned receiving circuit.

Hertz changed the frequency of his radiated waves by altering the inductance or capacity of his radiating conductor or antenna, and reflected and focused the electromagnetic waves, thus demonstrating the correctness of Maxwell's electromagnetic theory of light.

Lodge later in the same year read a paper on the " Protection of Buildings from Lightning "[3], before the Society of Arts, in which he described a number of interesting experiments on oscillatory discharges.

Great interest was excited by the experiments of Hertz, primarily on account of their immense scientific importance. It was not long, however, before several eminent scientists perceived that the property possessed by the Hertz waves of passing through fog and material obstacles made them particularly suitable for use for electric signaling.

Professor Elihu Thomson in a lecture delivered at Lynn, Mass., on "Alternating Currents and Electric Waves", in 1889, suggested this use.

Sir William Crookes in the *Fortnightly Review* for February, 1892, discussed the matter in some detail. I quote his statement in full as it shows what a clear conception he had of the possibilities and obstacles to be overcome:

> Here is unfolded to us a new and astonishing world, one which it is hard to conceive should contain no possibilities of transmitting and receiving intelligence.
>
> Rays of light will not pierce through a wall, nor, as we know only too well, through a London fog. But the electrical vibrations of a yard or

---

[1] Fitzgerald "On a method of producing Electromagnetic Disturbances of comparatively short wave lengths". *Report of British Association*, 1883.

[2] Hertz " Electric Waves ".

[3] Lodge *Society* of *Arts*, 1888.

more in wave length of which I have spoken will easily pierce such medium, which to them will be transparent. Here, then, is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present costly appliances. Granted a few reasonable postulates, the whole thing comes well within the realms of possible fulfilment. At the present time experimentalists are able to generate electrical waves of any desired wave-length from a few feet upwards, and to keep up a succession of such waves radiating into space in all directions. It is possible, too, with some of these rays, if not with all, to refract them through suitably shaped bodies acting as lenses, and so direct a sheaf of rays in any given direction; enormous lens-shaped masses of pitch and similar bodies have been used for this purpose. Also an experimentalist at a distance can receive some, if not all, of these rays on a properly constituted instrument, and by concerted signals messages in the Morse code can thus pass from one operator to another What, therefore, remains to be discovered is—firstly, simpler and more certain means of generating electrical rays of any desired wave-length, from the shortest, say of a few feet in length, which will easily pass through buildings and fogs, to those long waves whose lengths are measured by tens, hundreds, and thousands of miles; secondly, more delicate receivers, which will respond to wave-lengths between certain defined limits and be silent to all others; thirdly, means of darting the sheaf of rays in any desired direction, whether by lenses or reflectors, by the help of which the sensitiveness of the receiver (apparently the most difficult of the problems to be solved) would not need to be so delicate as when the rays to be picked up are simply radiating into space in all directions, and fading away according to the law of inverse squares.

I assume here that the progress of discovery would give instruments capable of adjustment by turning a screw or altering the length of a wire, so as to become receptive of wave-lengths of any preconcerted length. Thus, when adjusted to 50 yards, the transmitter might emit, and the receiver respond to, rays varying between 45 to 55 yards, and be silent to all others. Considering that there would be the whole range of waves to choose from, varying from a few feet to several thousand miles, there would be sufficient secrecy, for curiosity the most inveterate would surely recoil from the task of passing in review all the millions of possible wave-lengths on the remote chance of ultimately hitting on the particular wave-length employed by his friends whose correspondence he wished to tap. By " coding " the message even this remote chance of surreptitious straying could be obviated.

This is no mere dream of a visionary philosopher. All the requisites needed to bring it within the grasp of daily life are well within the possibilities of discovery, and are so reasonable and so clearly in the path of researches which are now being actively prosecuted in every capital of Europe that we may any day expect to hear that they have emerged from the realms of speculation into those of sober fact. Even now, indeed, telegraphing without wires is possible within a restricted radius of a few hundred yards, and some years ago I assisted at experiments where messages were transmitted from one part of a house to another without an intervening wire by almost the identical means here described.

The statement in the last paragraph of the quotation refers to the work of Professor David E. Hughes.[1] Professors Elihu Thomson and E. J. Houston in 1876 made a number of experiments and observations on high frequency oscillatory discharges.[2]

Professor Dolbear also suggested the same thing in an article in Donahoe's Magazine, March, 1893.

In fact the idea of using Hertzian waves for wireless telegraphy seems to have been quite widespread in the years immediately following Hertz's publications.

Fairly efficient means of generating electromagnetic waves of any desired length had been made known by Hertz. Vertical antennas connected with the ground had been previously used for sending and receiving by Dolbear in 1882 in connection with his system for telegraphing by electrostatic induction[3] and also later by Edison and others.

Hertz's receiver, the minute spark-gap, was not suited for wireless telegraphy and before any telegraphic work could be done a suitable receiver had to be found.

The fact that tubes containing conducting powders had their resistance altered by the discharge of a Leyden jar and that the original resistance could be restored by tapping the tube was first noted by Munk in 1835.[4]

In 1890 Branly showed that such a tube would respond to sparks produced at a distance from it.[5]

In 1892, at the meeting of the British Association at Edinburgh, Professor George Forbes suggested that such a tube would respond to Hertzian waves.

In 1893 Professor Minchen demonstrated experimentally that such powders would respond to electromagnetic waves generated at a distance.[6] He used a battery and galvanometer shunted around the powder to detect the effect of the waves.

Sir Oliver J. Lodge on June 1, 1894, delivered a lecture before the Royal Institution.[7] In this remarkable lecture Lodge described among other things the following:

---

[1] For Report of this work see *Electrician*, May 5, 1899.

[2] *Journal Franklin Institute*, April 1876.

[3] Dolbear U. S. patent 350,299, March 24, 1882.

[4] See Guthe "Coherer action" *Transactions of the International Electrical Congress*, St. Louis, 1904, page 242.

[5] Branley, *Comtes Rendues*, 1890, page 785, and 1891, page 90.

[6] Minchen, *Proceedings Physical Society*, London 1893, page 455.

[7] Sir O. J. Lodge, "The Work of Hertz", *Proceedings Royal Institution*, June 1, 1904, Vol. 14, page 321.

1. The filings coherer.
2. The filings coherer in hydrogen under reduced pressure (this in a note added July, 1894).
3. The automatic tapper back for the coherer.
4. The metallic reflector for focusing the waves.
5. The connection of the coherer to a grounded conductor; *i.e.*, a gas pipe system.
6. The method of making the coherer so connected respond by setting up oscillations in a separate grounded system, *i.e.*, a hot-water pipe system, in another part of the building.
7. The method of detecting distant thunder storms by connecting the coherer to a grounded gas pipe system.

In this lecture Professor Lodge stated that in his estimate the apparatus used would respond to signals at a distance of half a mile.

Early in 1895 Professor Popoff[1] of Cronstadt, Russia, constructed a very sensitive filings coherer, one form of which was used in some surveying experiments by the Russian government,[2] consisting of iron filings suspended by a magnet and resting upon a metallic plate or cup. He used early in 1895, the automatic tapping back mechanism, and substituted for the galvanometer an ordinary telegraphic relay. He operated this apparatus at a distance by means of a large Hertzian radiator. One terminal of his coherer was connected to a conductor fastened to a mast about 30 ft. high on the top of the Institute building and the other terminal of the coherer was grounded.

At the conclusion of his paper, which is dated December, 1895, Popoff made the following statement "In conclusion I can express the hope that my apparatus, with further improvements of same, may be adapted to the transmission of signals at a distance by the aid of quick electric vibrations, as soon as the source of such vibrations, possessing sufficient energy, will be found."

Among other experimenters who were working on this subject at the same time may be mentioned Captain Jackson of the British Navy, and Mr. A. C. Brown.

Marconi, on June 2, 1896, filed a provisional specification[3] showing two forms of apparatus, one similar to Lodge's 1894 apparatus using ungrounded aerials for both sending and receiving and the other for use "when transmitting through the earth or water" substantially identical with Lodge's 1894 and Popoff's 1895 apparatus, with tapper back etc., and the receiving antenna only being grounded.

---

[1] *Journal Russian Physico-Chemical Society*, Vol.27. April 25,1895,

[2] A. S. Popoff, " Apparatus for detection and registration of electrical vibrations ", *Journal Russian Physico-Chemical Society*, Vol. 28, Dec. 1895.

[3] Marconi, Great Britain patent, 12,039, 1896.

Soon after, in July 1896, Marconi arrived in England and made a number of experiments for the English Post Office at Salisbury Plain and elsewhere, using ungrounded aerials and parabolic reflectors and succeeded in reaching nearly two miles.

On March 2, 1897, Marconi filed the complete specification in which was included a statement that the transmitting antenna also could be grounded.

Lodge filed a provisional specification[1] showing radiating spheres but no antenna on May 10, 1897. The complete specification filed on Feb. 5, 1898, shows as one form both antennæ grounded and also the use of an inductance wound in the form of a coil for the purpose of diminishing the rate of damping of the waves.

So far as is known little work was done in America during this period. The writer made some experiments in 1896 and in conjunction with two of his students, Messrs. Bennett and Bradshaw, did considerable work on receivers of various type in the winter of 1896 and spring of 1897, the results of which were incorporated in a thesis.[2]

3. 1898. *Return to First Principles and Foundation, on lines Antithetical to Old, of New or Sustained Oscillation-non-microphonic Receiver Method.* Up to the year 1898, as may be seen from the above, the development of wireless telegraphy had proceeded along a single line. In that year, however, an entirely new method of wireless telegraphy was developed, characterized by a return to first principles, the abandonment of the previously used methods and by the introduction of methods in almost every respect their exact antitheses.

While the coherer is of more or less interest theoretically it is not adapted for use for telegraphic purposes. Responding as it does to voltage rises above a certain limit it does not discriminate between impulses of different characters, and is therefore peculiarly susceptible to interfering signals and atmospheric disturbances, and the operation of coherer systems cannot be

---

1. Lodge, Great Britain, patent, 11,575, 1897.
2. Western University of Pennsylvania, May, 1897.

guaranteed during the summer months or in the tropics. Roughly speaking a coherer acts by starting an arc and making a short-circuit on the line every time a signal is received, which short-circuit persists until it is broken by a blow from an additional mechanism, and such a method of operation is obviously far from practical. In addition it is practically impossible to obtain sharp tuning in a local circuit containing a coherer; its action is always more or less erratic, its electrostatic capacity variable, and it is insensitive.

At the sending end the energy which can be liberated by the discharge of an antenna is limited and in the form used prior to 1897 the dampening is so great that there are only a few oscillations per spark.

Lodge[1] by placing a coil of large inductance in the antenna throttled down the amount of energy radiated per oscillation and so obtained with the same limited amount of energy derived from the charged antenna, an increase in the time of dampening.

Braun[2] patented the method of using a local oscillatory circuit connected to an antenna, the local oscillatory circuit having a much longer period than the natural period of the antenna and of a different order of magnitude. Such a system, however, does not radiate energy appreciably, and produces a damped wave.

This dampening and the limited amount of energy obtainable by charging and discharging the antenna operates to prevent sharp tuning and working over long distances.

The coherer is well adapted for working with damped waves, but the coherer-damped wave method can never be developed into a practical telegraph system. It is a question whether the invention of the coherer has not been on the whole a misfortune as tending to lead the development of the art astray into impracticable and futile lines and thereby retarding the development of a really practical system.

The fact that no coherer-damped wave system could ever be developed into a practically operative telegraph system, and the fact that it was necessary to return to first principles and initiate a new line of development along engineering rather than laboratory lines was perceived in America in 1898[3] and a new method was advised which may be called the Sustained Oscillation-non-microphonic Receiver method as opposed to the Damped Oscillation-coherer method previously used.

---

[1] Lodge, Great Britian, patent 11,575, 1897.

[2] Braun, German patent 11,578, Oct. 14, 1898.

[3] *Proceedings American Institute of Electrical Engineers*, Nov. 1899, p. 635 and Nov. 20, 1906, p. 781.

4. *Fundamental Differences between the Old and New Wireless Schools.* The differences between the two methods are shown in tabulated form:

	Damped Oscillation-coherer Method		Sustained Oscillation-non-microphonic Method.
A1:	Damped oscillations are produced at the sending end.	A1:	Sustained oscillations are produced at the sending end.
2:	The energy transmitted is obtained by charging the antenna and discharging it.	2:	The energy transmitted is derived from a local source and not from the antenna.
3:	A spark gap is used for producing the oscillations.	3:	An arc or high frequency dynamo is generally used for producing the oscillations.
B1:	Imperfect or microphonic contact receivers are used.	B1:	Non-microphonic contact receivers are used.
2:	The action of the receiver depends upon the voltage rise and is independent of the amount of energy received.	2:	The receiver response is determined by the integral amount of energy received.
3:	An open tuned circuit is used for receiving.	3:	A closed tuned circuit is used for receiving.
4:	The receiving circuit is tuned to the wave frequency only.	4:	The receiving circuit may be tuned to a group frequency as well as to the wave frequency.
C1:	In transmitting messages the production of the electromagnetic waves is intermittent.	C1:	The waves are preferably generated continuously and the transmission accomplished by changing the character of the wave.
2:	The wave energy flux is intermittent.	2:	The wave energy flux is constant.
3:	A high voltage is used.	3:	A low voltage is used.
4:	Comparatively short wave lengths are used.	4:	Comparatively long wave lengths are used.

5:	The signals consist of dots and dashes, whose interpretation is fixed.	5:	The signals may consist of dots only, whose interpretation depends on the station sending and receiving.
D1:	Antennæ are used adapted, roughly speaking, to utilize the electrostatic component of the electromagnetic waves.	D1:	The antennæ are preferably arranged so as to utilize the other component of the electromagnetic waves instead of the electrostatic component.

The history of these two antithetical lines of development will be treated of separately.

5. *Period* 1898–1902 A. *Development and Perfecting of Sustained Oscillation-non-microphonic Receiver Method* (a) *The current-operated receiver.* The first essential for the development of the system was, of course, a quantitatively responsive receiver. Several forms of this were tried including the modification of the Boys' radio-micrometer (consisting of a light thermo couple suspended in the field of a permanent magnet and heated by radiation from a wire which in turn was heated by the current to be detected) described by the writer at the Columbus meeting of the American Association in 1897.[1] This was abandoned in favor of Professor Elihu Thomson's alternating-current galvanometer[2] suitably modified for telegraphic work.[3]

Among other forms of current-operated receiver may be mentioned the following.

The *Hot-wire Barretter*,[4] consisting of a minute platinum wire a few hundred thousandths of an inch in diameter and approximately a hundredth of an inch in length. The term " barretter " was coined for this device for the reason that it differs essentially from the bolometer of Langley in that it is arranged to be affected by external sources of radiant heat as little as possible instead of as much as possible, and, to have an extremely small specific heat, an object not sought in the case of the bolometer.

The *Liquid Barretter*[5] in which the change of resistance is effected by heating a liquid, the concentration of path being obtained by means of a fine platinum wire point. Some question has been raised as to the theory of operation of this device but I think there is no question but that the effect is due to heat, though what per cent. of the effect is due to change in ohmic conductivity by heat and what per cent. is due to depolarization by heat is still, as originally stated by the writer,[1] uncertain. The facts that the device operates practically equally well irrespective of which terminal is connected to the local battery, and that the effect varies as the square of the alternating current (as a heat operated device should do) instead of directly with the alternating current as a rectifier would do, and that depolarization is produced by the heat, have been confirmed by Dr. L. W. Austin.[2] The writer has experimentally determined the fact that though the electrical impulses may have a duration of less than a millionth part of a second the change in resistance persists for approximately the ten thousandth part of a second, which would seem to show conclusively that the action is not a *direct* effect of the waves.

---

[1] *Electrician*, June 24, 1904.

[2] Elihu Thomson, U. S. patent 363,185, Jan. 26, 1887.

[3] U. S. patents 706,736 and 706,737, Dec. 15, 1899.

[4] U. S. patent 706,744, June 6, 1902.

[5] U. S. patent 727,331, April 9, 1903.

(b) *Methods of Obtaining Sustained Oscillations.* 1. *Spark-gap and Local Oscillatory or "tank" Circuit.* Professor Elihu Thomson discovered that by using a transformer without an iron core (the well known Elihu Thomson air-core transformer, later used by Tesla and others), and a spark-gap and condenser in the primary circuit and with the secondary circuit suitably tuned great resonant rises of potential could be obtained. In 1892 he constructed such a transformer giving discharges 64 inches long.[3]

The same method was later used by Tesla[4] in his experimental researches and in his attempt to carry out Loomis'[5] method of transmitting a current through a hypothetical conducting stratum in the upper regions of the atmosphere.

The device, suitably modified for wireless telegraphic purposes, so as to give instead of a continuously cumulative rise of potential an initial rise of potential followed by a gradual feeding in of the energy from the local circuit to supply the energy lost from radiation, was made use of in 1898 for the purpose of producing prolonged trains of sustained waves.

Various types of connection between the antenna and the local oscillatory circuit were tested but it was found that the

---

1. *Ibid.*
2. Austin, *Bulletin of the Bureau of Standards*, Vol. 2 No. 2.
3. *Electrical World*, Feb. 20 and 27, 1892.
4. U. S. patent 645,516, Sept. 2, 1897.
5. Loomis, U. S. patent, 129,971, July 30, 1872.

most efficient results were obtained by connecting the local circuit directly across the spark-gap.[1]

The results of some comparative tests are here given. The figures in the column " A " are for the local circuit connected directly to the terminals of the spark-gap, those in column " B " are for an auto-transformer, those in column " C " for a loose coupled primary and secondary.

	A	B	C
Frequency	212,000	212,000	212,000
Tank capacity	0.072 m.f.	0.072 m.f.	0.072 m.f.
Kilowatt output dynamo	30	30	30
Tank current	400 amperes	370 amperes	300 amperes
Antenna current	48.5	46.	48.

The large station at Brant Rock is operated with the local circuit directly connected across the spark-gap, partly because the efficiency is somewhat greater but also on account of the great simplification of connections and the fact that the degree of sustainment of the wave train may be adjusted very simply, if desired, by sliding the lower terminal of the antenna along a few inches of the lead of the local oscillatory circuit.

Cooper Hewitt[2] in 1902 used a modification of his mercury lamp to obtain intermittent discharges each followed by a train of high frequency oscillations.

2. *Arc methods.* The worker with high frequency oscillatory currents will soon discover that we are indebted to the genius of Professor Elihu Thomson for practically every device of any importance in this art.

The method of producing high frequency oscillations from an arc and continuous current was discovered by him in 1892.[3] Fig. 1, taken from his patent, shows the general form of his arrangement. If the directions given in the specification are followed no difficulty will be met with in obtaining frequencies as high as 50,000 per second.

Between 1900 and 1902 some experiments were carried out with the Elihu Thomson arc as a source of high frequency oscillations for wireless telegraphy and telephony.

Some difficulties were found, for example the arc could not be started and stopped as quickly as was necessary for telegraphic purposes and the intensity of the oscillations and their frequency varied considerably. These were overcome by making some minor improvements, for example the difficulty in sending was overcome by permitting the arc to run continuously and using the key to change the electrical constants of the circuits.[1] The difficulty in keeping the intensity and frequency constant was overcome by substituting resistance for a portion of the inductance, and also by using the arc under pressure.[2]

---

[1] U. S. patents 706,735 and 706,736, Dec. 15, 1899.

[2] Cooper Hewitt, U. S. patent 780,999, April 25, 1902.

[3] Elihu Thomson U. S. patent 500,630, July 18, 1892.

Tests made by Dr. Austin[3] show that with this method frequencies as high as 3,000,000 per second and efficiencies as high as 60% can be obtained together with an absolutely steady generation of the high frequency currents and an absence of harmonic frequencies.

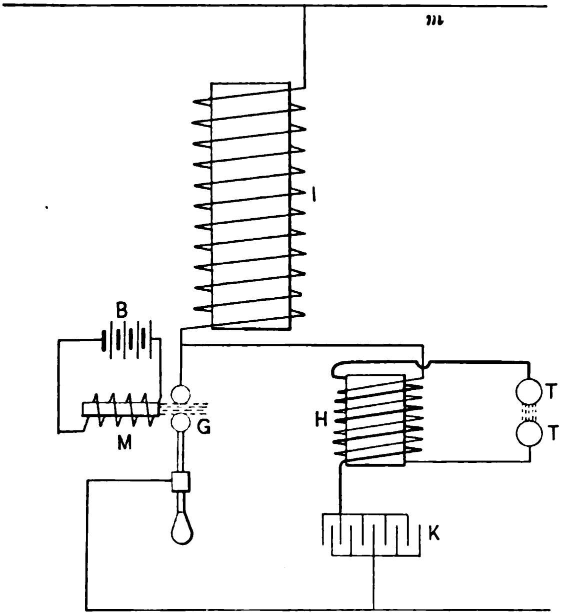


Fig.1

3. *High frequency alternator.* The first high frequency alternator was built by Professor Elihu Thomson in 1889.[4] And it

---

[1] U. S. patents 706,742, July 6, 1902, 706,747, Sept. 28, 1901, 727,330, March 21, 1903, 730,753, April 9, 1903.

[2] *Ibid* and U. S. patent 706,741.

[3] Austin, *Bulletin of the Bureau of Standards*, Vol. 3, No. 2.

[4] Thomson, *Elec.Engineer*, July 30,1890 and *London Elec.*,Sept.12,1890.

was while experimenting with it in 1900 that Dr. Tatum made his very interesting discovery that high frequency currents of large amperage could be passed through the body without injury.[1]

From 1898 to 1900 numerous experiments were made on antennæ of large capacity and it was found that instead of using sheets of solid metal or wire netting, single wires could be placed at a considerable fraction of the wave-length apart and yet give practically the same capacity effect as if the space between them were filled with solid conductors.

From other investigations on the variation of radiation with frequency the result was arrived at that it should be possible to construct an alternating-current dynamo of sufficiently high frequency and output to give ample radiation for wireless telegraphic purposes.[2]

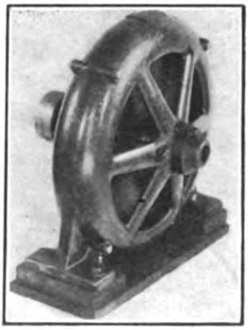


Fig. A

In 1900 a large American electrical manufacturing company kindly consented to take up the construction of such a dynamo. As a preliminary, a dynamo of 1 kw. output and 10,000 cycles (shown in Fig. A) was built in 1902. By the summer of 1906 many of the difficulties had been overcome and a machine giving 50,000 cycles was installed at the Brant Rock station. Various improvements were made by the writer's assistants, and in the fall of 1906 the dynamo was working regularly at 75,000 cycles, with an output of half a kilowatt and was being used for telephoning to Plymouth, a distance of approximately 11 miles. In the following year machines were constructed having a frequency of 100,000 cycles per second and outputs of 1 and 2 kilowatts.

---

[1] Thomson, *Elec. Engineer*, March 11, 1891.

[2] U. S. patent 706,737, May 29, 1901.

The credit for the development of this machine is due to Messrs. Steinmetz, Haskins, Alexanderson, Dempster, and Geisenhoner and also to the writer's assistants, Messrs. Stein and Mansbendel.

(*c*) *Closed tuned circuits.* In 1898 the open tuned circuits originally used were discarded for closed tuned circuits[1] and it was discovered that valuable selective effects could be obtained by placing the condenser in shunt to the inductance instead of in series with it.[2]

(*d*) *Combination of wave and group tuning.* The fact that if selectivity is obtained solely by tuning to wave frequencies, the number of stations is limited, was appreciated at an early date. In 1900[3] a new method was developed, the stations being tuned both to the wave frequency and to an independent or group frequency, so that stations might obtain selectivity by varying either the wave or the group frequency and thus have at their disposal a virtually unlimited number of combinations and be practically free from atmospheric disturbances. Fig. C shows a type of group tuner.

(*b*) *Further development of damped wave-coherer method.* Marconi by 1898 had carried the development of the filings coherer to its maximum point.

Lodge in 1897[4] had disclosed the open secondary circuit for receiving.

Marconi in 1898[5] greatly improved this by adjusting the length of the secondary so as to tune it, and by the aid of this improvement was enabled to telegraph a distance of 35 miles[6] in October, 1899.

Lodge in 1902[7] invented what is perhaps the most perfect form of coherer, consisting of a thin steel disc dipping in oil covered mercury and automatically decohered by being kept in continuous rotation.

A number of self-restoring coherers of which the Brown[8] carbon coherer may be taken as a type, including the mercury carbon coherer of Solari, came into more or less extended use, and also modifications of the imperfect contact receiver of Neugschwender.[1]

---

[1] U. S. patents 706,735 and 706,736, Dec. 15, 1899.

[2] *Ibid.*

[3] U. S. patents 727,325, June 2, 1900, and 727,330 March 21, 1903.

[4] Lodge, Great Britain patent, 11,575, May 10, 1897

[5] Marconi, Great Britain patent, 12,326, June 1, 1898.

[6] Official report U. S. Navy of test U. S. S. Massachusetts, Oct. 1899.

[7] Lodge, Muirhead and Robinson, Great Britain patent, 13,521, June 14, 1902.

[8] Brown and Neilson, Great Britain patent, 28,955, Dec. 17, 1896.

The small progress made along these lines is to be explained by the fact that the damped wave-coherer system is essentially and fundamentally incapable of development into a practical system.

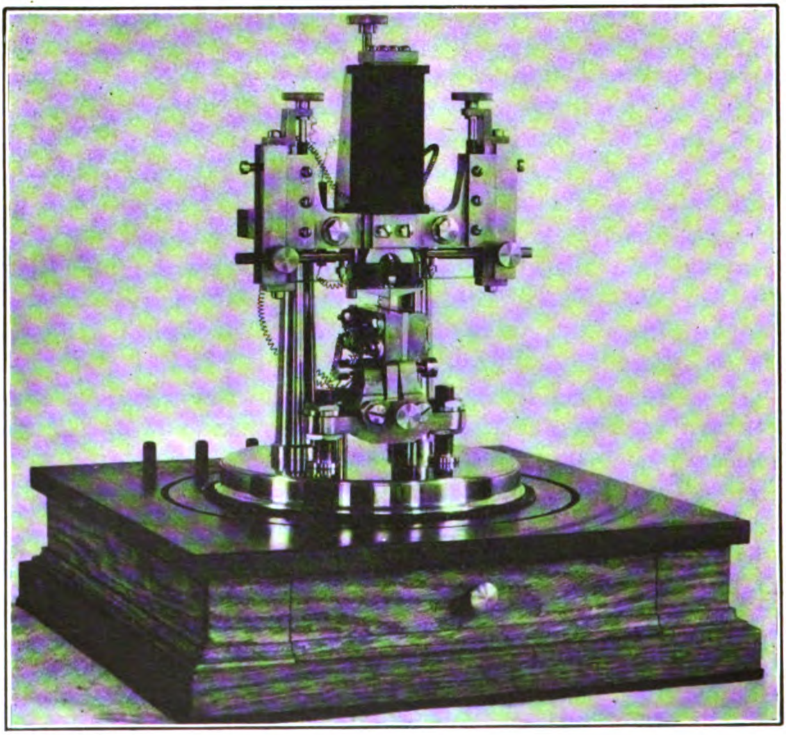


Fig. C.

Period 1902–1908—*Later Developments.* Progress in Europe since 1902 has been marked by the gradual abandonment of the elements of the damped wave-coherer system and the substitution of elements of the sustained wave non-microphonic contact type.

In 1900[2] Marconi substituted for the plain aerial an aerial with the writer's tuned local circuit or tank circuit for sending, thus obtaining a considerable increase in range of transmission.

---

[1] A. Neugschwender, *Wied. Ann. der Physik*, 1899, vol. 67, p. 430.

[2] Marconi, Great Britain, patent, 7,777, Apr. 26, 1900.

In 1902, Marconi invented a very ingenious form of current operated receiver, called the magnetic detector[1], and with this combination achieved some very remarkable results.

In 1905 Professor Fleming[2] invented a very efficient detector based on the " Edison effect " in incandescent lamps, and the observations of Elster and Geitel[3] on the rectifying effect of such an arrangement on Hertzian oscillations.

Virtually nothing was done in Europe in the way of producing sustained oscillations by the arc or high frequency method until recently, possibly because of Duddell's erroneous statement[4] to the effect that frequencies much above 10,000 could not be obtained by the Elihu Thomson arc method, and Fleming's statement[5] that an abrupt impulse was necessary and that high frequency currents, even if of sufficient frequency, could not produce radiation.

In 1903 Poulsen[6] invented an interesting modification of the Elihu Thomson arc, which consists in forming the arc in hydrogen instead of in air or compressed gas as previously done. This modification is not, however, so efficient as the older methods and gives oscillations varying in amplitude and intensity and accompanied by strong harmonics,[7] but I have considered it worth mentioning on account of the amount of interest it appears to have excited in Europe.

Some very important and interesting papers on electrical oscillations were published during these years by Oberbeck,[8] Wien,[9] Drude,[10] and Bjerknes.[11]

In America the development of the sustained oscillation non-microphonic system has proceeded steadily and it may now be said to have reached the stage of commercial practicability.

---

1. Marconi, Great Britain, patent, 10,245, 1902.
2. Fleming, *Proceedings Royal Society London*, 1905, Vol. 74.
3. Elster and Geitel, *Wied. Ann der Physic*, Vol. 52, page 433.
4. Duddell, *The Electrician*, 1903, Vol. LI, page 902.
5. Fleming, *Proceedings of the International Congress, St. Louis*, 1904, Vol. 3, page 603.
6. Poulsen U. S. patent 789,449, June 19, 1903.
7. Austin, *Bulletin of the Bureau of Standards*, Vol. 3 No. 2.
8. Oberbeck Wied. *Ann. der Physik*, Vol. 55, 1895.
9. *Wied Ann. der Physik* Vol. 8, 1902.
10. Drude *Ann. der Physik*, Vol. 13, 1904.
11. Bjerknes, *Ann. der Physik*, Vol. 44, 1891, and Vol. 47, 1892.

On account of the amount of work which has been done it would be impossible to refer to more than a few of the recent advances.

The following are some of the later types of detectors:

The *frictional receiver*,[1] in which the waves produce a change of friction between two moving surfaces and so cause an indication.

The *heterodyne receiver*,[2] in which a local field of force actuated by a continuous source of high frequency oscillations interacts with a field produced by the received oscillations and creates beats of an audible frequency.

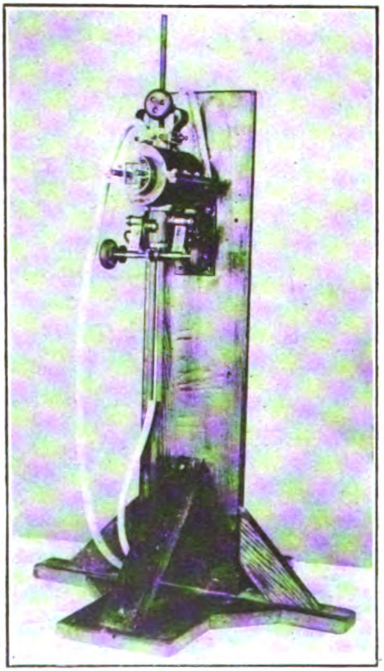


FIG. B.

The so called *thermoelectric receivers* of Austin,[3] Pickard[4] and Dunwoody.[5]

The "*audion*" *of deForest*,[6] a very interesting and sensitive device, which though superficially resembling Professor Fleming's rectifier appears to act on an entirely different principle.

---

[1] U. S. application, 251,538, March 22, 1905.

[2] U. S. application, 271,539, June 28, 1905.

[3] Austin, U. S. application, 319,241, May 29, 1906.

[4] Pickard, U. S. application, 342,465, Nov. 8, 1906.

[5] Dunwoody, patent, 837,616, March 23, 1906.

[6] deForest, U. S. patent, 836,070, Jan. 18, 1906.

The *Cooper Hewitt mercury receiver*, about which little is known but which appears to be very sensitive.

The following are some of the later methods of producing sustained oscillations:

The *substitution of a number of arcs in series having terminals of large heat capacity* in place of the single arc in the arc method.[1]

The *use of regulating or " fly-wheel " circuits* in connection with the arc method.[2]

The *method of producing oscillations* shown in Fig. B by using two arcs and throwing the discharge from one side to the other alternately at a frequency regulated by the constants of the electric circuit.[3]

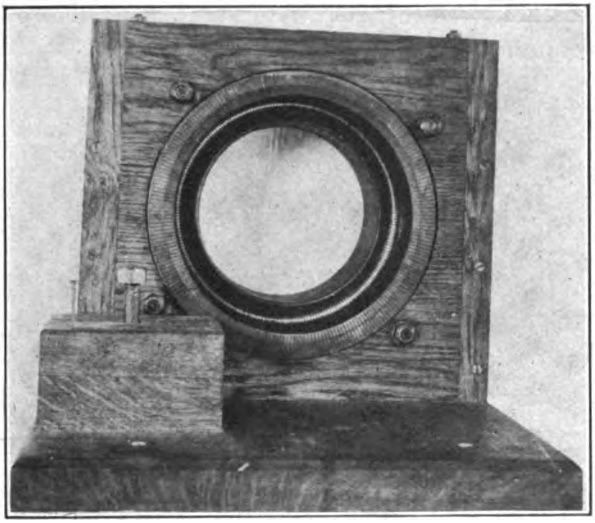


Fig. C.

The *condenser dynamo*[4] which consists of two radially slotted discs separated by a mica diaphragm, charged by a continuous current source of potential, and rotating in opposite directions.

Two-phase high frequency dynamo method.[5]

---

[1] U. S. application, 291,737, Dec. 14, 1905.

[2] *Ibid.*

[3] *Ibid.*

[4] U. S. application, 291,739, Dec. 14, 1905.

[5] U. S. patent, 793,649, March 30, 1905.

Commutator method.[1] In this method the high frequency is produced by means of a ball rotating at high speed on the interior surface of a commutator. Shown in Fig. C.

The *helium arc method*[2] in which the arc is produced in helium or argon or similar gases.

The *critical pressure method*[3] in which the electrodes extend within a certain critical distance, depending upon the pressure used, so that the discharge always passes at the same voltage irrespective of the distance between the electrodes.

Methods of Signaling. Continuous production of waves but changing constants of sending circuit.[4]

The *inverted method* of sending and the method of signaling by sending dots, the interpretation of which is determined by similar commutators at the sending and receiving stations.

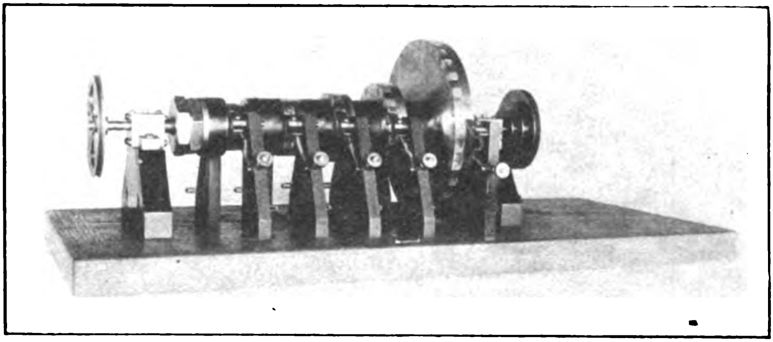


FIG. L.

Duplex and Multiplex Methods. A considerable number of these have been worked out, mostly operating either by balance methods[5] or commutators.[6] It is impossible to discuss all the various improvements, such for example as the method of indicating the busy and free state of a station, the methods of sending and receiving in one direction, the various types of aerials used for receiving the other components of the electromagnetic waves besides the electrostatic component, etc.

---

[1] U. S. application, 316,521, May 12, 1906.

[2] U. S. application, 351,560, Jan. 7, 1907.

[3] U. S. application, 355,787, Feb. 4, 1907.

[4] U. S. patents 706,747, Sept. 28, 1901; 706,742, June 6, 1902; 727,747, March 21, 1903.

[5] U. S. application, 366,528, April 5, 1907.

[6] U. S. patent, 793,652, April 6, 1905.

Fig. L shows the harmonic interrupter for determining the variation of intensity with change of note.

Fig. M shows a type of receiver described in U. S. Patent 706,747, in which the telephone diaphram is formed of thin copper and repelled by a fixed coil having a resistance of about 16 ohms. The principle of this receiver was discovered by Professor Elihu Thomson. It has been used for wireless telephony for a distance of 11 miles with fairly satisfactory results.

Fig. N shows a transformer used in the transmitting circuit. The number of primary and secondary turns can be altered continuously, and also the degree of coupling. The wire is wound off from an insulating cylinder onto a cylinder of copper, and the cylinder of copper, forming a closed circuit secondary of the transformer, annuls the inductance of that portion of the wire wound upon the copper cylinder.

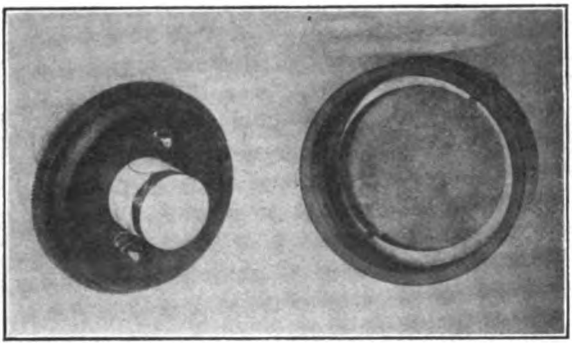


Fig. M.

Fig. O shows an apparatus for determining the best shape of coil for use with the heterodyne receiver.

Fig. P shows a group-tuned call; that is, a vibration galvanometer which operates a selenium cell and rings a bell when a call is received.

C. Theory of Wireless Telephony

For wireless telephony three things are necessary:

1. Means for radiating a stream of electrical waves sufficiently continuous to transmit the upper harmonics on which the quality of the talking depends.
2. Means for modulating this stream of waves in accordance with the sound waves.

3. A continuously responsive receiver giving indications proportional to the energy received, and capable of responding with sufficient rapidity to the speech harmonics.

Work on the wireless telephone was commenced before a satisfactory means was discovered for producing sustained oscillations.

To ascertain the number of sparks per second which was necessary to determine articulate speech, a phonograph cylinder was taken and grooves were cut in it longitudinally. It was found in this way that practical transmission could be accomplished with 10,000 breaks per second. It is believed now that this number is unnecessarily high, possibly owing to the fact that it was impossible to cut the grooves on the cylinder without producing ridges. The lower limit may be fixed in another way.

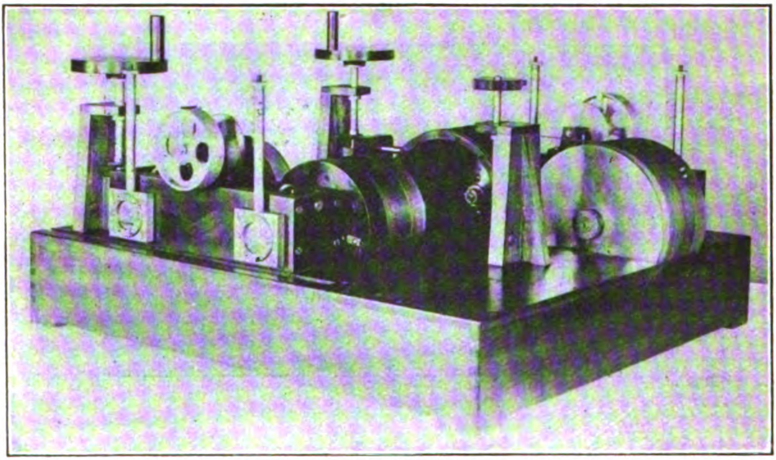


FIG. N.

Electrical circuits met with in actual working have resistance, self inductance capacity, and leakance. Heaviside gave the differential equations for the pressure and current over such circuits when alternating voltages were applied, but no method of solution being known the mathematical treatment of such circuits was restricted to cases where one of the constants was neglected, until Dr. A. E. Kennelly in a masterly series of papers gave the complete solution.

The results were immediately found applicable to a great variety of problems, such as the transmission of signals through cables and of telephonic speech through various types of circuits.

In this way Dr. Kennelly[1] by comparing the results obtained by Dr. Hammond V. Hayes[2] in practical telephonic transmission over loaded lines with the theoretical values of the current for different harmonics showed that harmonics above 2,000 per second could be neglected for telephonic transmission.

The writer has never succeeded in obtaining good talking with such a low frequency, but under favorable conditions fairly satisfactory speech may be obtained with 5,000 interruptions per second. For really good transmission, however, the radiation must be practically continuous, for if the spark frequency is less than 20,000 per second there is a disagreeable high pitch note in the telephone, not noticeable perhaps at first but apt to become annoying with use. The most satisfactory way is, of course, to use a source of sustained oscillations.

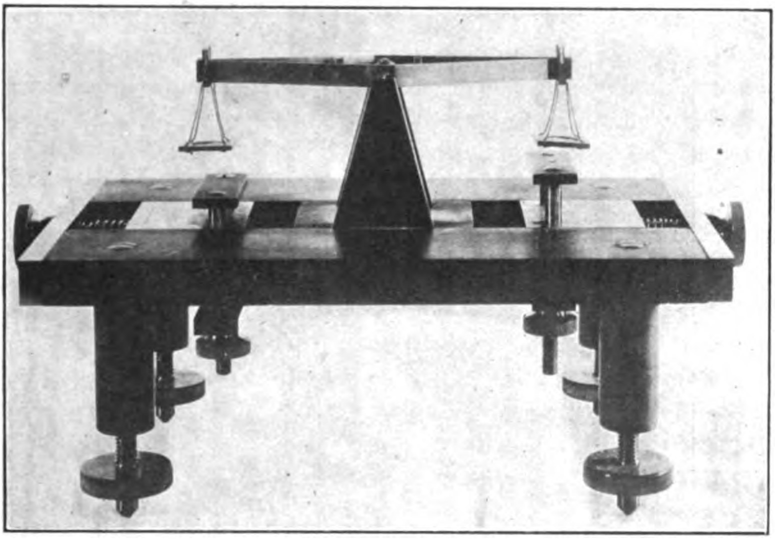


FIG. O.

It fortunately happens that for wireless telephonic purposes it is inadvisable to use a wave frequency of less than 25,000 per second, on account of the difficulty in radiating energy with low frequencies.

---

[1] Kennelly, " Distribution of Pressure and Current over Alternating Current Circuits ", *Harvard Engineering Journal*, 1906, page 43.

[2] Hayes, " Loaded Telephone Lines in Practice ", *Transactions International Electrical Congress*, St. Louis, Vol. 3.

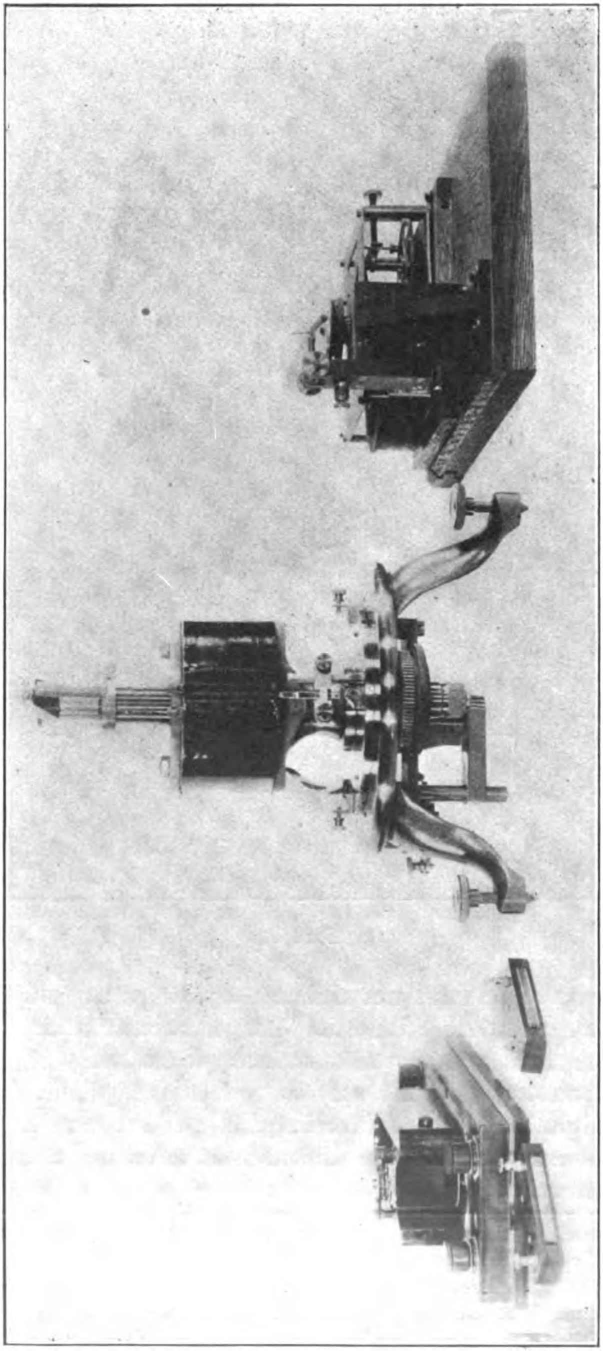


Fig P.

The receiver must, of course, be continuously responsive. If, for example, it had to be tapped back in order to restore it to the responsive condition, speech could not be transmitted.

It must also give indications proportional to the energy received or the character of the speech will be distorted.

It must also respond with sufficient rapidity. If, for example, it takes a thousandth of a second to restore itself to its original resistance the receiver will obviously not record the higher harmonics. I have experimentally determined that a receiver which restores itself in the ten thousandth part of a second acts with sufficient rapidity.

D. HISTORY OF THE DEVELOPMENT OF WIRELESS TELEPHONY

The writer has been asked on several occasions how the wireless telephone came to be invented. In November, 1899, shortly prior to the delivery of my previous paper,[1] while experimenting with the receiver shown in Fig. 3 of that paper, I made some experiments with a Wehnelt interrupter for operating the induction coil used for sending.

In the receiver mentioned the ring of a short-period Elihu Thomson oscillating current galvanometer rests on three supports, *i.e.*, two pivots and a carbon block, and a telephone receiver is in circuit with the carbon block. A storage battery being used in the receiver circuit[2] it was noticed that when the sending key was kept down at the sending station for a long dash the peculiar wailing sound of the Wehnelt interrupter was reproduced with absolute fidelity in the receiving telephone. It at once suggested itself that by using a source with a frequency above audibility wireless telephony could be accomplished.

Professor Kintner, who was at that time assisting me in these experiments and to whose aid their success is very largely due, was kind enough to make the drawings for an interrupter to give 10,000 breaks per second. Mr. Brashear, the celebrated optician kindly consented to make up the apparatus and it was completed in January or February, 1900.

The experimental work was, however, delayed as the writer was at that time transferring his laboratory from Allegheny, Pa., to Rock Point, Md., and it was not until six months later that the stations at that point were completed and a suitable mast was erected for trying the apparatus.

---

[1] *Transactions American Institute Electrical Engineers*, Nov. 22, 1899.

[2] U. S. patent, 706,736, December 15, 1899.

The first experiments were made in the fall of 1900 with the above mentioned apparatus which was supposed to give 10,000 sparks per second but which probably gave less. Transmission over a distance of one mile was attained but the character of the speech was not good and it was accompanied by an extremely loud and disagreeable noise, due to the irregularity of the spark.

By the end of 1903 fairly satisfactory speech had been obtained by the arc method above referred to, but it was still accompanied by a disagreeable hissing noise. In 1904 and 1905 both the arc method and another method in which the 10,000 cycle alternator above referred to was employed, had been developed to such an extent that the apparatus could be used practically and sets were advertised and tendered to the U. S. Government.[1] The transmission was, however, still not absolutely perfect.

By the fall of 1906 the high frequency alternator had been brought to a practical shape and was used for telephoning from Brant Rock to Plymouth, a distance of 11 miles, and to a small fishing schooner,[2] this being the first instance in which wireless telephony was put in practical use. The transmission was perfect and was admitted by telephone experts to be more distinct than that over wire lines, the sound of breathing and the slightest inflections of the voice being reproduced with the utmost fidelity.

---

[1] Letter of July 8, 1905; see *The Electrician*, London, Feb. 22, 1907; also catalogue of 1904 and subsequent.

[2] An amusing instance may be mentioned as illustrating the incredulity with which the wireless telephone was received. Some of the local papers having published an account of the experiments with the schooner above referred to the following appeared under the heading "Current News and Notes" in the columns of a prominent technical journal, Nov. 10, 1906.

"A New Fish Story.—It is stated from Massachusetts that the wireless telephone has successfully entered into the deep sea fishing industry. For the last week experiments have been conducted by the wireless telegraph station at Brant Rock, which is equipped with a wireless telephone, with a small vessel stationed in the fleet of the South Shore fishermen, twelve miles out in Massachusetts Bay. Recently, it is asserted, the fishermen wished to learn the prices ruling in the Boston market. The operator on the wireless fitted boat called up Brant Rock and telephoned the fishermen's request. The land operator asked Boston by wire and the answer was forwarded back to the fishermen. This is a rather fishy fish story".

The doubt expressed was, however, only natural. I remember the astonishment displayed by one of the company's new operators some months previously on placing the receiving telephone to his head while the vessel was almost out of sight of land and hearing the operator at the land station call his name and begin to talk to him.

As it was realized that the use of the wireless telephone would be seriously curtailed unless it could be operated in conjunction with wire lines, telephone relays were invented both for the receiving and transmitting ends and were found to operate satisfactorily, speech being transmitted over a wire line to the station at Brant Rock, retransmitted there wirelessly by a telephone relay, received wirelessly at Plymouth and there relayed out again on another wire line. On Dec. 11, 1906, invitations were issued to a number of scientific men to witness the operation of the wireless transmission in conjunction with the wire lines.[1] A report of these tests appeared in the American Telephone Journal of Jan. 26 and Feb. 2, 1907, the editor being one of the men present.

In July 1907 the range was considerably extended and speech was successfully transmitted between Brant Rock and Jamaica, Long Island, a distance of nearly 200 miles, in daylight and mostly over land,[2] the mast at Jamaica being approximately 180 ft. high.

In 1907 several European experimenters succeeded in transmitting speech wirelessly, using some of the earlier forms of the writer's arc method, and some months ago the vessels of our Pacific squadron were equipped with wireless telephones, using this arc method, by another American company.

---

[1] Brant Rock, Mass., Dec. 11, 1906.
American Telephone Journal, 100 William St., New York City.

Dear Sirs: A limited number of invitations have been issued to witness the operation of the National Electric Signaling Co's. wireless telephone system between Brant Rock and Plymouth, Mass., over a distance of between ten and eleven miles.

The tests will be as follows:

1. Transmission of ordinary speech, and also transmission of phonographic talking and music by wireless telephone between Brant Rock and Plymouth.
2. Transmission of speech over ordinary wire line to wireless station at Brant Rock, relaying the speech there automatically by telephone relay and automatically transmitting the speech by wireless to Plymouth, transmitting same at Plymouth automatically directly or by telephone relay over regular wire line.

Invitations have been issued to the following gentlemen, (here follows list of some of the guests, including Dr. A. E. Kennelly, Professor Elihu Thomson, etc., and a request to the company to send a representative).

Yours very truly,
National Electric Signaling Co.

[2] "Long Distance Wireless Telephony," *The Electrician*, Oct. 4, 1907.

E. METHODS AND APPARATUS

1. *Methods and apparatus for producing the electromagnetic waves.* These have been already referred to. Fig. 2 shows a rotating spark-gap giving approximately 20,000 discharges per second. This was connected to a 5,000-volt source of direct current. The terminals are of 40% platinum-iridium. In operation the apparatus is arranged to charge a condenser to a definite potential and discharge it.

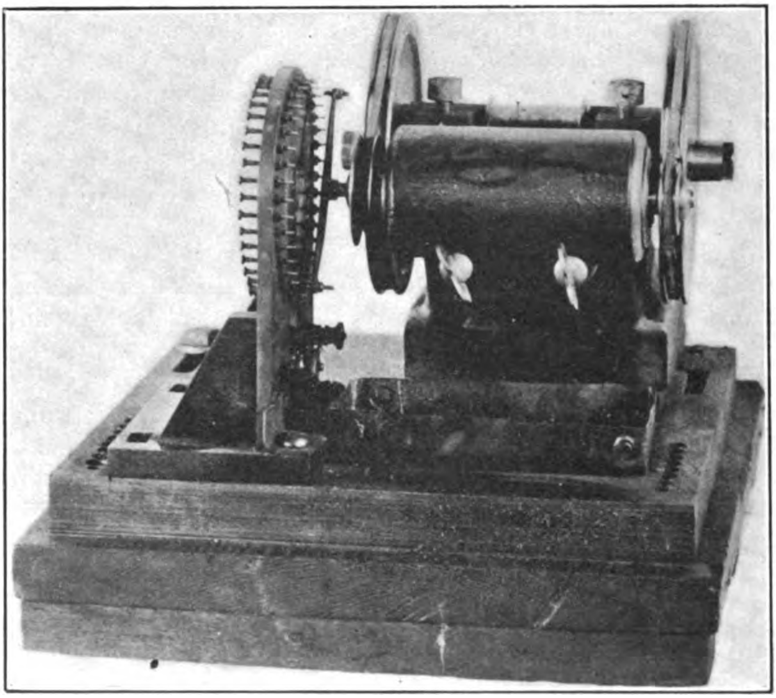


FIG. 2.

Figs. 3 and 4 show forms of apparatus for operating the arc in a gas under pressure.

The apparatus of Fig. 4 is also used for the arc in vacuum and the critical distance arc.

Fig. 5 shows a multiple gap with rotating electrodes, brass, amalgamated zinc and graphite being used.

Fig. 6 shows a multiple arc gap with electrodes of different materials, the upper terminals being water cooled.

Fig. 7 shows a condenser dynamo.

Fig. 8 shows a general view of one type of high frequency alternator. It is driven by a motor and a DeLaval gear. It has been operated at 96,000 cycles per second, but is generally run at 81,700.

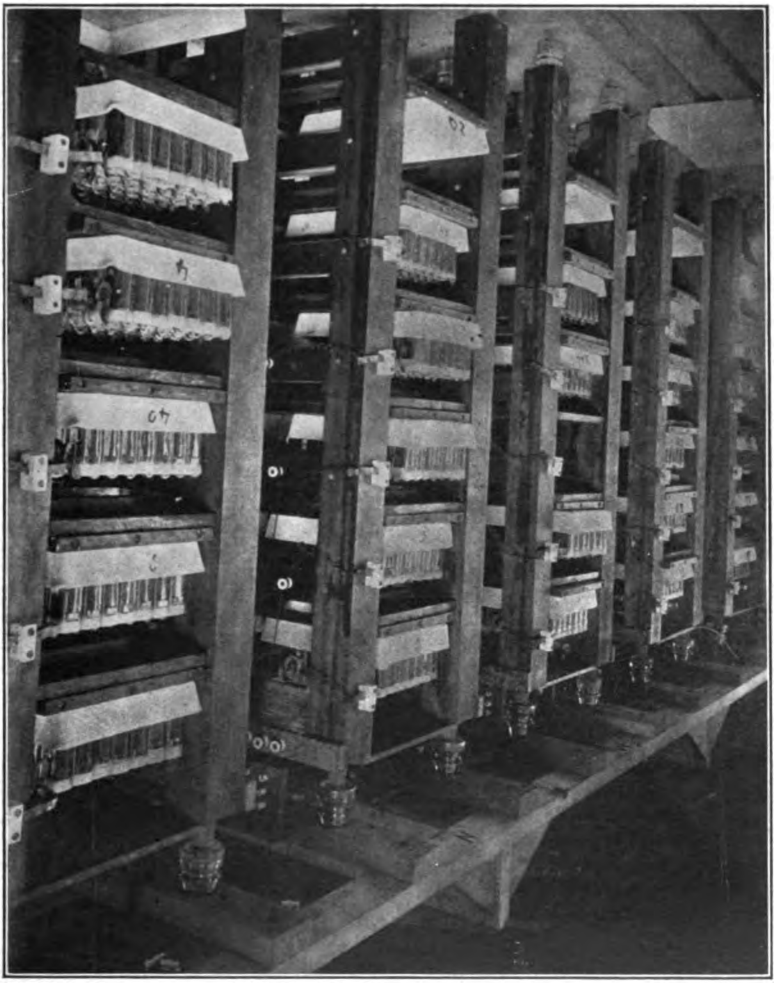


Fig. 3.

Fig. 9 shows a field disc; it is 12 inches in diameter and there are 300 slots on it.

Fig. 10 shows the armature and field coils. There are 600 armature slots each containing two turns of 13 mil wire. The field current is 5 amperes. The resistance of the armature is 6 ohms; it gives 160 volts and about 7 or 8 amperes. Other armatures have been constructed having a resistance of 4 ohms. For some work double armatures are used giving about 270 volts. The output of the single armature machines at 81,700 cycles is approximately one kilowatt. The output of the double armature machine is approximately 2 kilowatts.

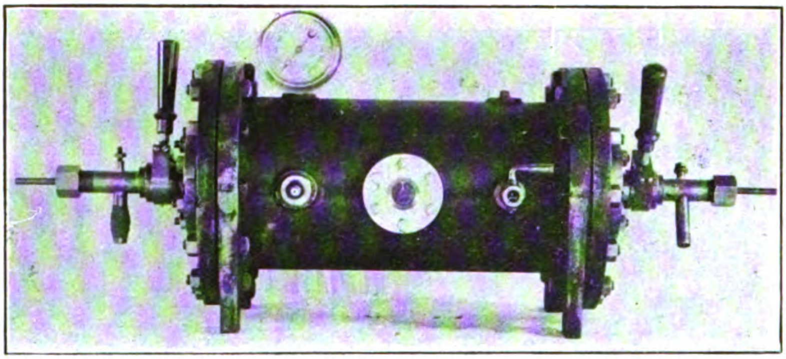


FIG. 4.

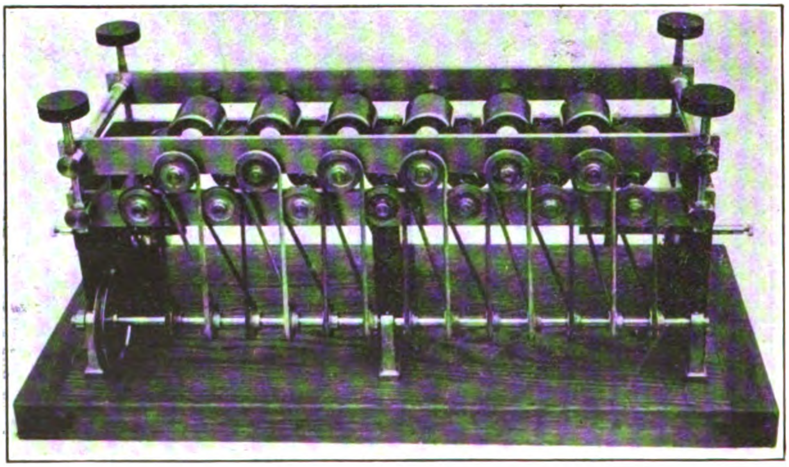


FIG. 5.

Other types of high frequency alternators are under construction. One type shown in Fig. 11 is designed for use on shipboard. The armature disc is 6 inches in diameter and two armatures are used. It is arranged to be mounted on gimbals and to be driven by a steam turbine connected to the steam pipe by flexible armored steam hose. The frequency is about 100,000 and the output about 3 kilowatts.

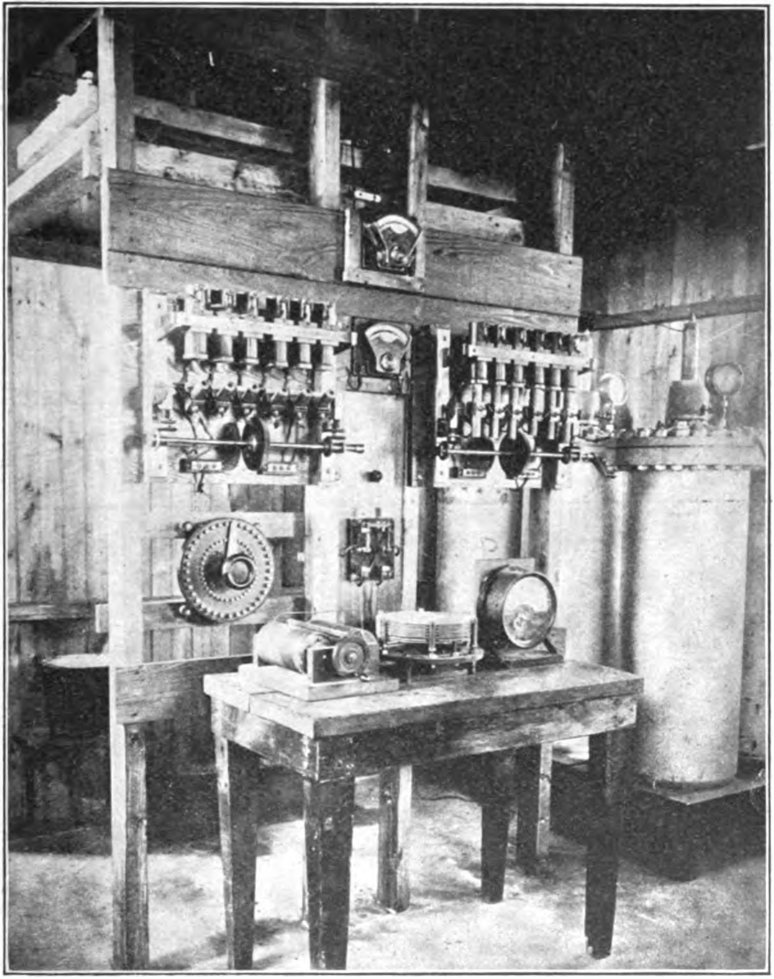


FIG. 6.

Another type, which is at present being constructed by Mr.

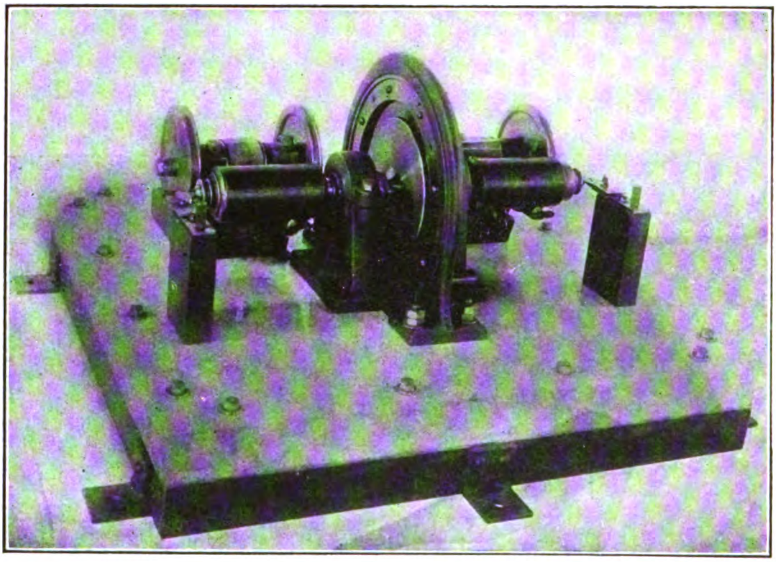


FIG. 7.

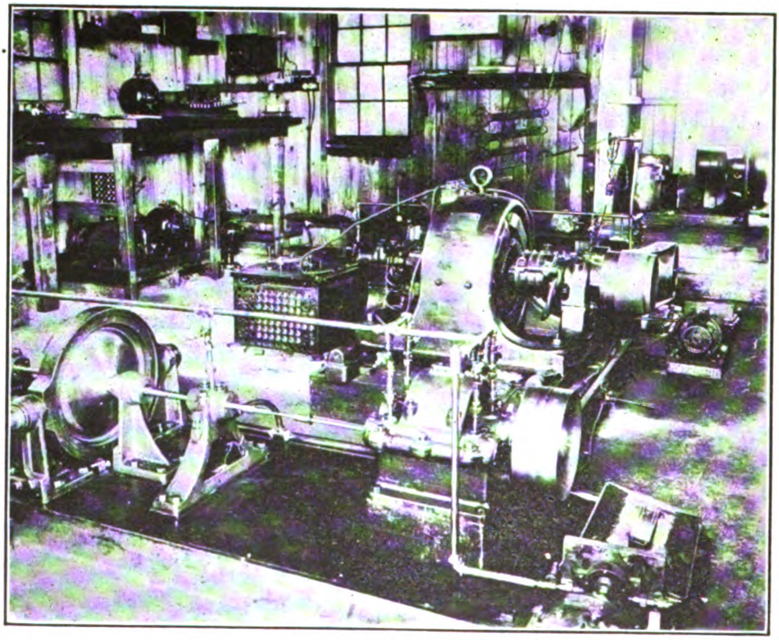


FIG. 8.

Alexanderson, to whose efforts the success of this type of generator is largely due, is designed to have an output of 10 kilowatts. Designs have been made for a generator of still larger size with a calculated output of 50 kilowatts and a frequency of 50,000. This machine is intended for Translantic work.

For some of these machines, instead of driving by gear or steam turbine, a special two-cycle motor has been devised, to operate at a frequency of 500 cycles per second.

The high frequency alternator method is believed to possess a number of advantages over other methods, inasmuch as it is set in operation by merely opening a steam valve and has no complicated electrical apparatus or circuits of any kind. The speed is regulated by the steam pressure, this being accomplished by an electrically operated reducing valve.

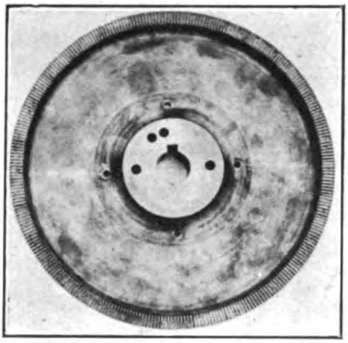


Fig. 9.

For measuring the frequency various speed indicators have been tried, but it has been found that the best way is to use a resonant circuit with an ammeter shown in Fig. D in it,[1] this being an extremely sensitive means of indicating the frequency and in addition affording a means of automatically keeping the speed constant to a small fraction of a per cent. The reducing valve is adjusted so that if left to itself the machine will run slightly above speed. As soon as it reaches one-tenth of one per cent. higher than its designed speed the resonance begins to fall and a contact is opened which slightly throttles the steam. In this way the frequency is kept varying between the limits of one-tenth of one per cent. above speed and one-tenth

---

[1] *Electrical World and Engineer*, Nov. 11, 1899.

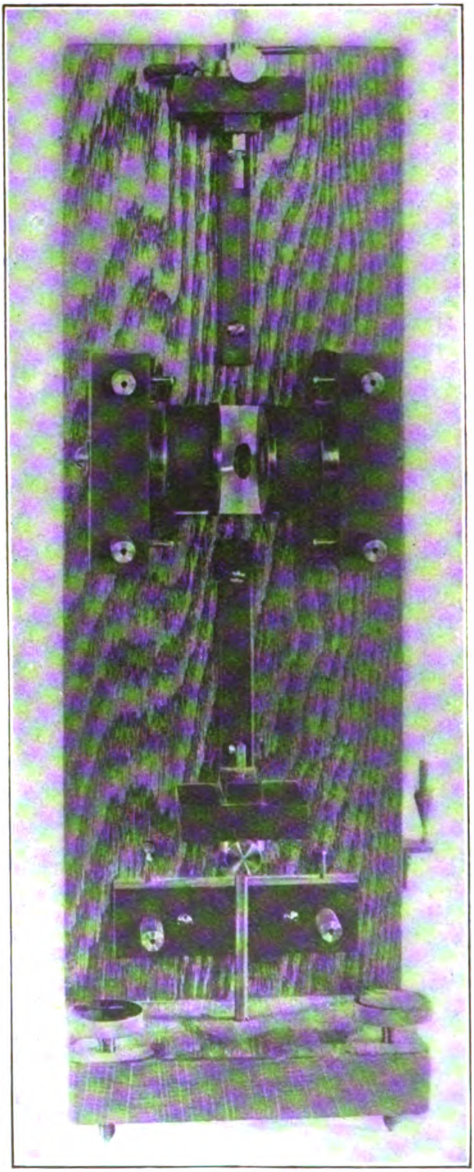


FIG. D.

of one per cent. below speed. Where the drive is electric instead of by turbine, a storage battery is used to drive the two-phase generator and even better results may be obtained as regards regulation than with steam.

2. *Transmitters.* The types of transmitters most commonly used are the carbon transmitter and static transmitter, and the carbon transmitter relay.

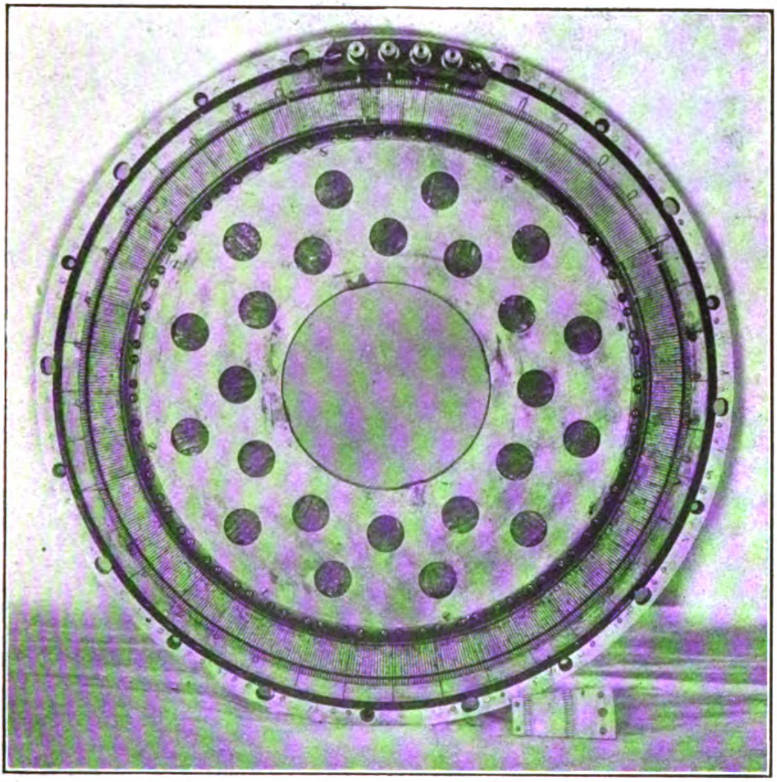


FIG. 10.

Fig. 12 shows the standard type of carbon transmitter.

It was found that the ordinary carbon transmitter was unsuited for wireless telephonic work on account of its inability to handle large amounts of power. A new type of transmitter was therefore designed which the writer has called the " trough " transmitter. It consists of a soapstone annulus to which are clamped two plates with platinum iridium electrodes. Through

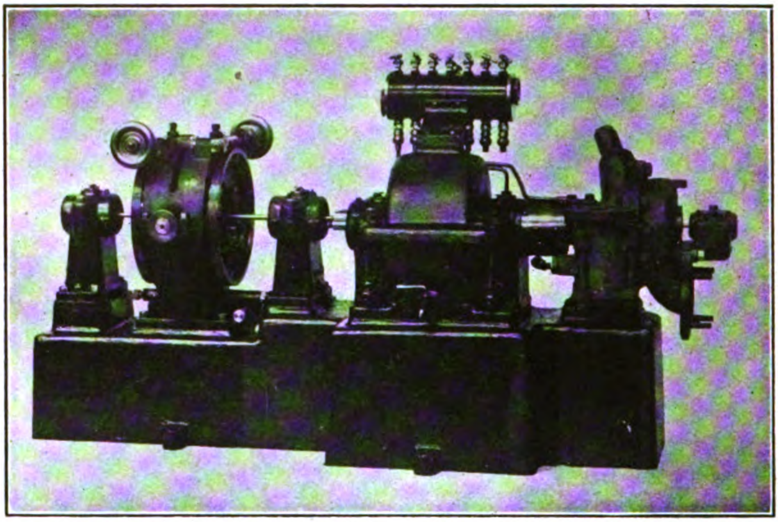


FIG. 11.

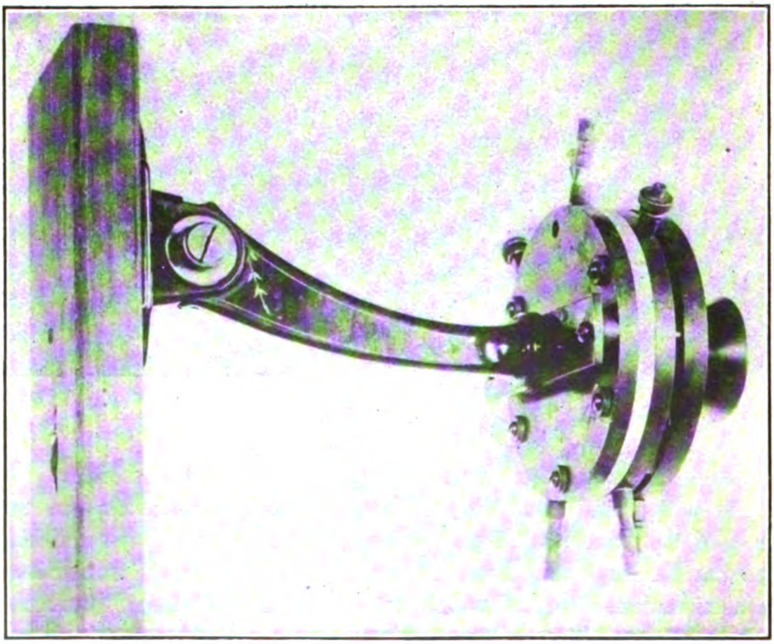


FIG. 12.

a hole in the center of one plate passes a rod, attached at one end to a diaphragm and at the other to a platinum iridium spade. The two outside electrodes are water-jacketed.

This transmitter requires no adjusting. All that is necessary is to place a teaspoonful of carbon granules in the central space. It is able to carry as much as 15 amperes continuously without the articulation falling off appreciably. It has the advantage that it never packs. The reason for this appears to be that when the carbon on one side heats and expands the electrode is pushed over against the carbon on the other side. These transmitters have handled amounts of energy up to one-half horse power, and under these circumstances give remarkably clear and perfect articulation and may be left in circuit for hours at a time. Fig. 13 shows a modified form with split back.

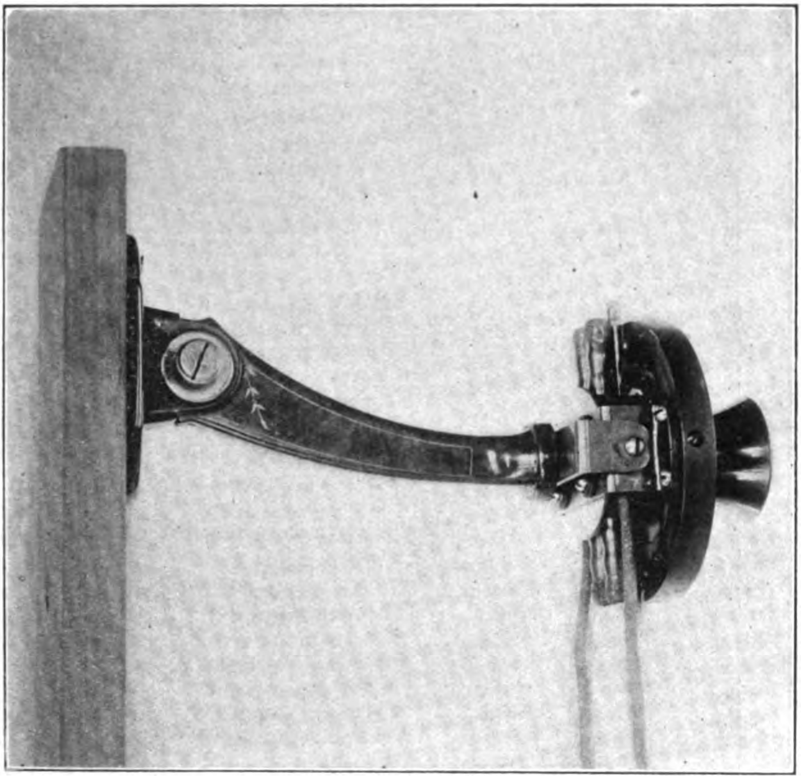


Fig .13.

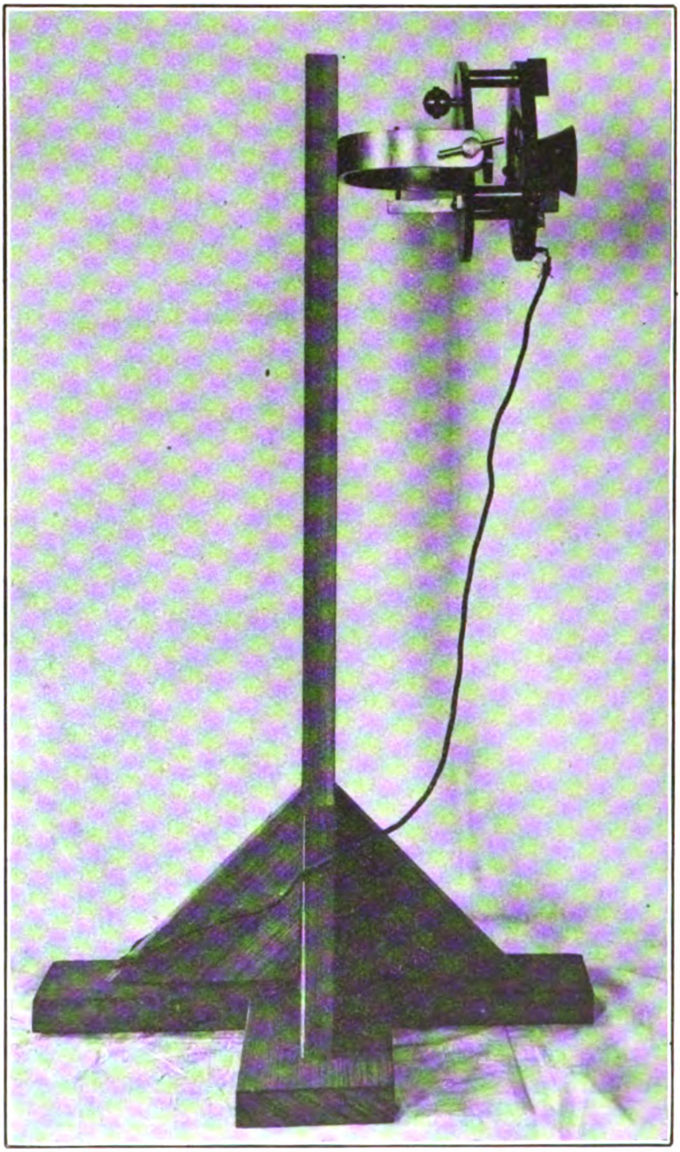


FIG. 14.

Fig. 14 shows a type of condenser transmitter in which the vibration of the diaphragm alters the electrical capacity of the transmitter, thus throwing the circuit in and out of tune or spilling more or less energy through a leakage circuit.

Fig. 15 shows a transmitting relay for strong currents. The only thing noticeable about this is that the telephone magnet is a differential one.

Fig. 16 shows another type of transmitting relay, for amplifying very feeble currents. It will readily be understood that where a person in Albany, for example, wishes to talk to another person on board a ship off New York, the wireless station being located near New York, the volume of the transmission received at New York will not be very strong, and while it may be possible to transmit it without amplification, amplification is advisable.

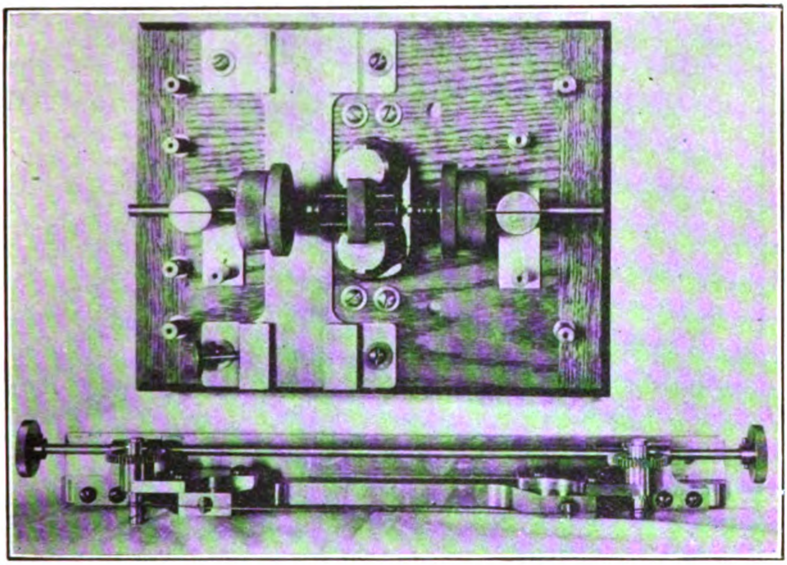


FIG. 15.

This receiver is a combination of the differential magnetic relay and the trough transmitter. An amplification of fifteen times can be obtained without loss of distinctness. The side electrodes of the trough are water-jacketed. The successful amplification depends upon the use of strong forces and upon keeping the moment of inertia of the moving parts as small as possible. Amplification may also be obtained by mechanical means but as a rule this method introduces scratching noises which are very objectionable even though comparatively faint.

Other types of transmitters have also been used, such as liquid jet transmitters, Fig. 17 transmitters operating by closing the air-gap in a magnetic circuit, and so changing the inductance of the oscillating circuit, etc.

Fig. E shows a loud-speaking telephone receiver. A small iron disk is placed opposite a nozzle through which air at high pressure is blown. As is well known, this causes the disk to be held close to the nozzle. The telephone magnets alter the position of the disk and thus produce very loud talking.

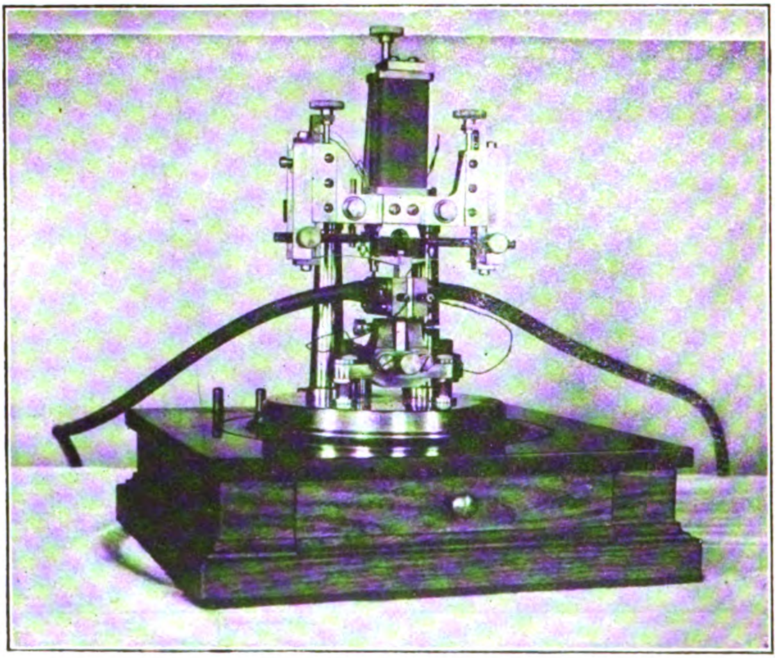


FIG. 16.

The transmitting relays are connected in the wire line circuit in the same way as the regular telephone relay, except that in place of being inserted in the middle of the line they are placed in the wireless station and an artificial line is used for balancing. There is no difficulty met with on the wireless side of the apparatus, but on the wire line side there are the well-known difficulties due to unbalancing which have not yet been entirely overcome. For the correction of these difficulties, therefore, we must look to the engineers of the wire telephone companies. At present the difficulties are if anything less than those met with in relaying on wire lines alone.

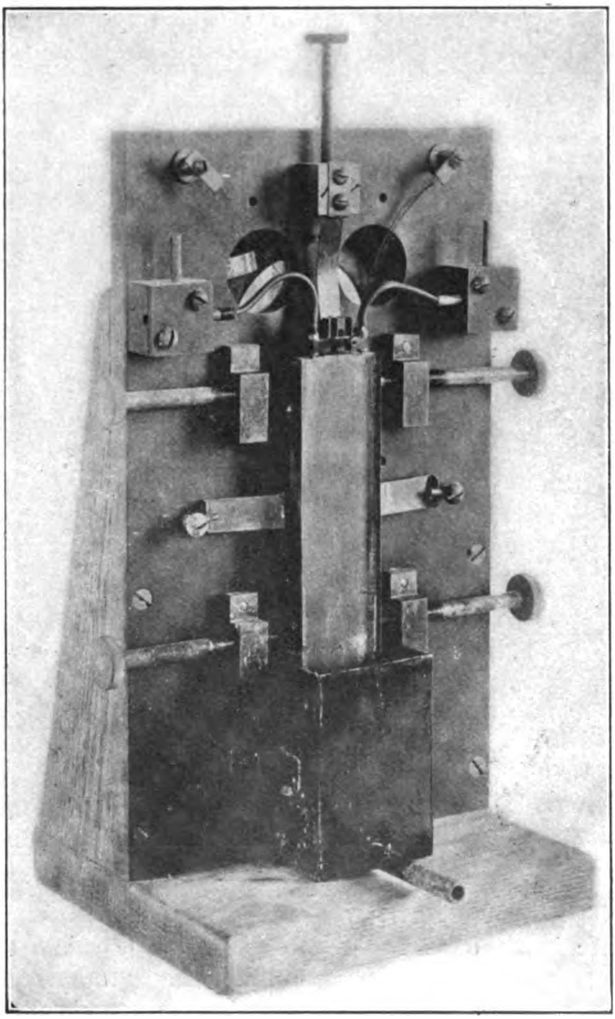


FIG. 17.

3. *Transmitting circuits.* Fig. 18[1] shows a type of arc circuit.

---

[1] U. S. patents Nos. 706,742, June 6, 1902 and 730,753, April 9, 1903.

Fig. 19[1] shows a suitable type of connection for use with a high frequency alternator.

Fig. 20[2] shows a type of circuit for use with the condenser transmitter.

Fig. 21[3] shows a type of circuit in which the modulation is accomplished by changing the inductance of one of the oscillating circuits.

As a matter of fact the transmitter may be placed almost anywhere in the circuit between the arc or dynamo and the antenna, or between the arc or dynamo and ground, or in the transformer circuit, or in shunt to an inductance or capacity, the results obtained in all cases being indistinguishable. The sole criterion of success seems to be that the transmitter should be capable of handling the energy and the circuit should be

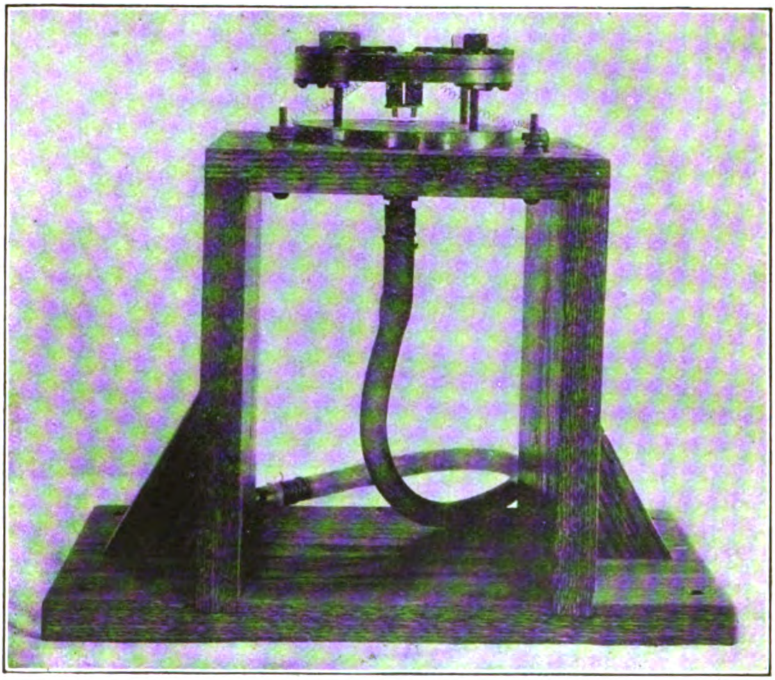


Fig. E.

---

[1] U. S. patent No. 706,742, June 6, 1902.

[2] U. S. patent No. 706,747, Sept. 28, 1901.

[3] U. S. patent No. 706,747, Sept. 28, 1901.

properly adjusted. Some success has also been attained by placing the transmitter in the field of the dynamo[5] but this method requires very careful designing of the field circuit.

4. *Receivers.* The receiver which the writer has found most satisfactory for general purposes is the liquid barretter. Fig. 22 and 23 shows this receiver. It consists of a fine platinum wire, about a ten thousandth of an inch in diameter immersed in nitric acid. Tests made with this receiver show that it responds without apparent loss of efficiency to notes as high as 5000 per second. Some very careful measurements recently made by my assistants, Messrs. Glaubitz and Stein, give the following results:

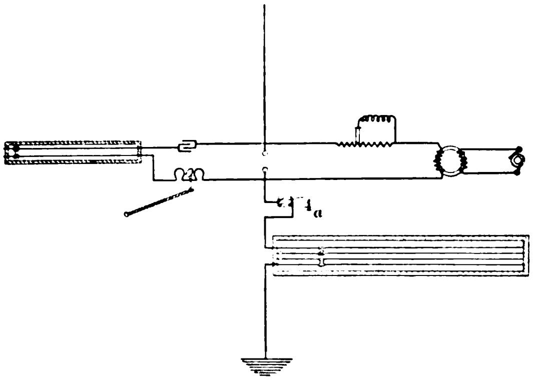


Fig. 18

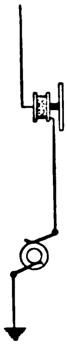


Fig. 19

Voltage of high frequency circuit necessary to produce readable signals,	15×10^{-5} volts.
Ohmic resistance of receiver,	2,500 ohms.
Value of high frequency current necessary to produce readable signals,	6×10^{-5} amperes.
Electromagnetic wave energy required to produce audible note for period of one second,	1×10^{-4} ergs.

The telephone used for detecting the signals had a resistance of approximately 1000 ohms. Some measurements were made to determine the change of current in the telephone circuit by using a sensitive galvanometer in series with the telephone but the results obtained were obviously too low, possibly on account of the electrostatic capacity of the turns of the galvanometer with respect to each other. It will be noted that the amount of electromagnetic wave energy necessary to produce a signal is considerably less than that given in a previous note.[1] The difference is possibly to be attributed to improvements in adjustment and operation.

---

[5] U. S. patent No. 793,649, March 30, 1905.

The above measurements were taken by shunting the barretter across a piece of straight resistance wire in series with a hot-wire ammeter, to determine the voltage necessary, and by introducing resistance in series with the barretter to determine the resistance of the barretter. The figures were also checked in a number of other ways and very concordant results were obtained, so that it is believed they may be relied upon.

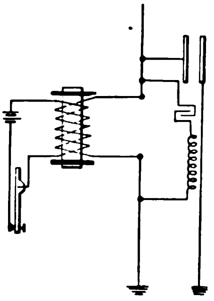


Fig. 20

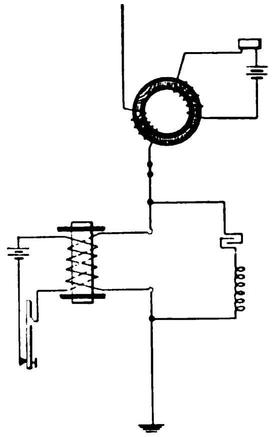


Fig. 21

The previously mentioned thermoelectric receivers or rectifiers of Dr. Austin and Mr. Pickard shown in Figs. 24 and 25 and the vacuum tube receivers of Fleming, deForest, and Cooper Hewitt also act very satisfactorily. The fact that the writer has not been able to get as good results from them may be due to greater familiarity with the liquid barretter and heterodyne receiver.

Figs. 26, 27, and 28 show a form of heterodyne receiver adapted for use for telephonic work.

---

[1] *Electrical World and Engineer*, Oct. 31, 1905.

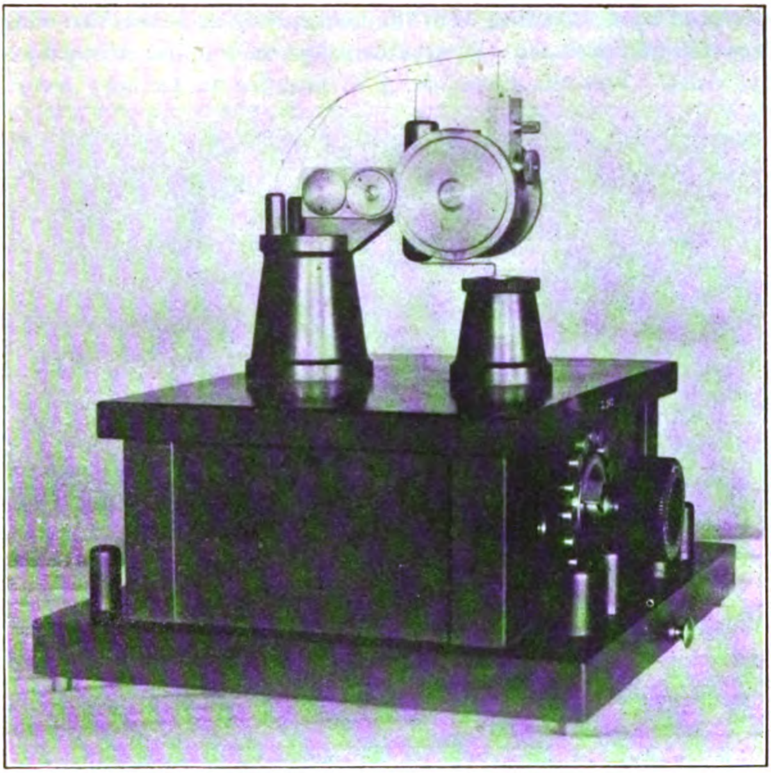


FIG. 22.

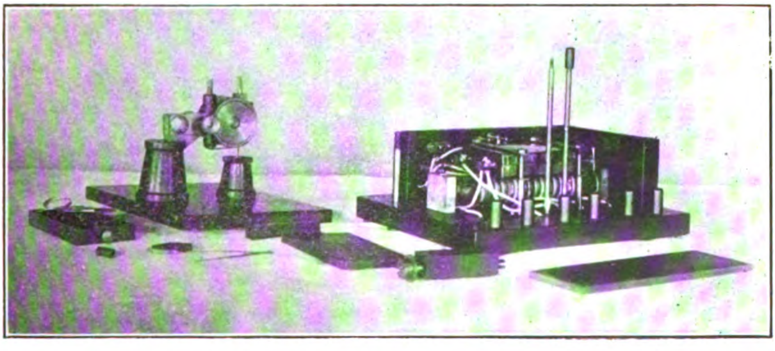


FIG. 23.

5. *Receiver connections.* Where the wireless telephone is operated by first talking into the transmitter and then throwing a switch and listening, the usual wireless telegraphic connections are used. This has been found in practice to be very inconvenient, however, and several methods have therefore been devised for talking and listening simultaneously, which methods can, of course, also be applied to duplex wireless telegraphy.

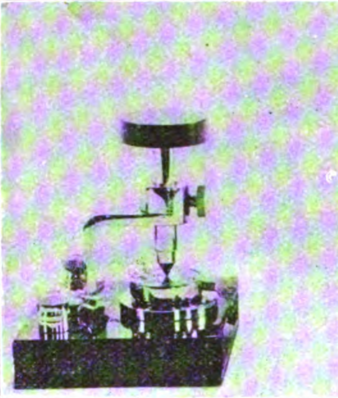


FIG. 25.

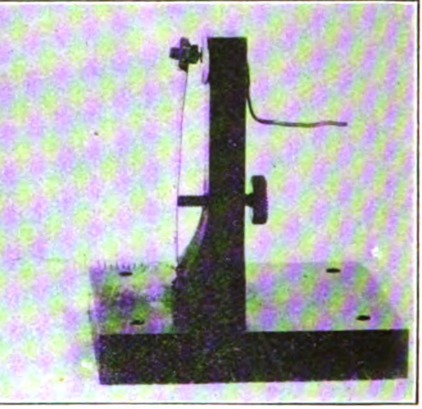


FIG 24.

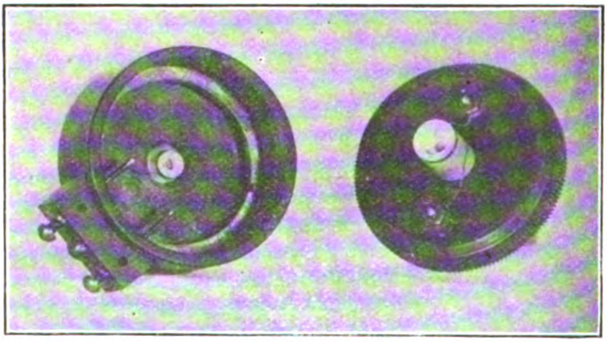


FIG. 26.

Among these methods may be mentioned the commutator method[1] and the balance method.[2]

The former method is fairly well known and consists in rapidly connecting alternately the transmitter and receiver. The balance method consists in using a phantom aerial as shown in Fig. 29, where *P* is a phantom aerial, the circuit having such capacity inductance and resistance as to balance the radiating antenna. The apparatus is shown in Fig. H.

---

[1] U. S. application, 350,199, Dec. 31, 1906.

[2] U. S. application, 366,528, April 5, 1907,

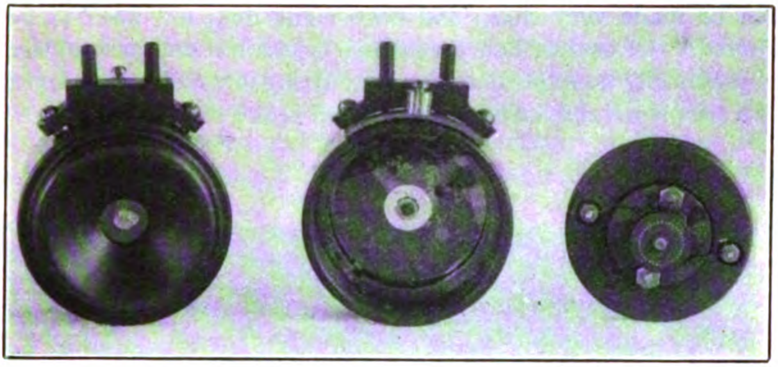


FIG. 27.

In order entirely to cut out disturbances in the receiver while sending, an interference preventer, *I. P.*, the elements of which are shown in Figs. I and J, is used in the receiving circuit.

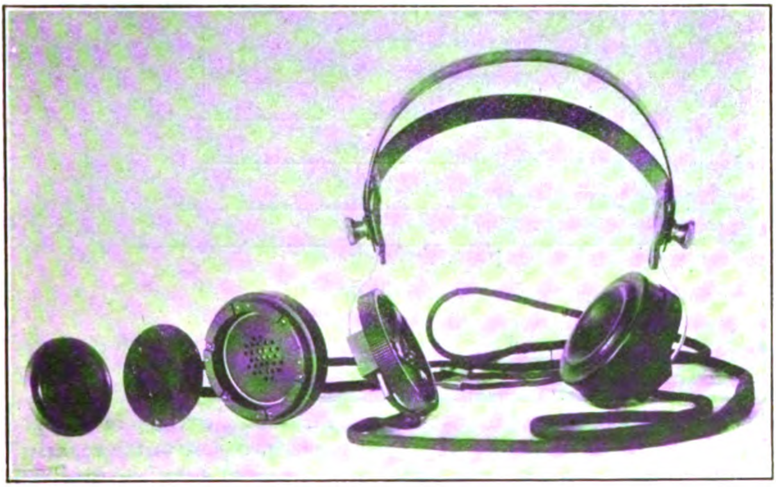


FIG. 28.

It may be here mentioned that balance methods work much better with wireless telephony and telegraphy than with line telephony and telegraphy, for the reason that the radiation resistance of an antenna is absolutely definite and is not affected by the weather, as are line circuits. Consequently, the balance can be made very sharp and once made does not need to be altered.[1] Of course, half the energy is lost but this is a matter of practically no importance, as the cutting down of the strength of a telephonic conversation to one-half is as a rule hardly noticeable, especially where there are no line noises or distortion of the speech through capacity effects.

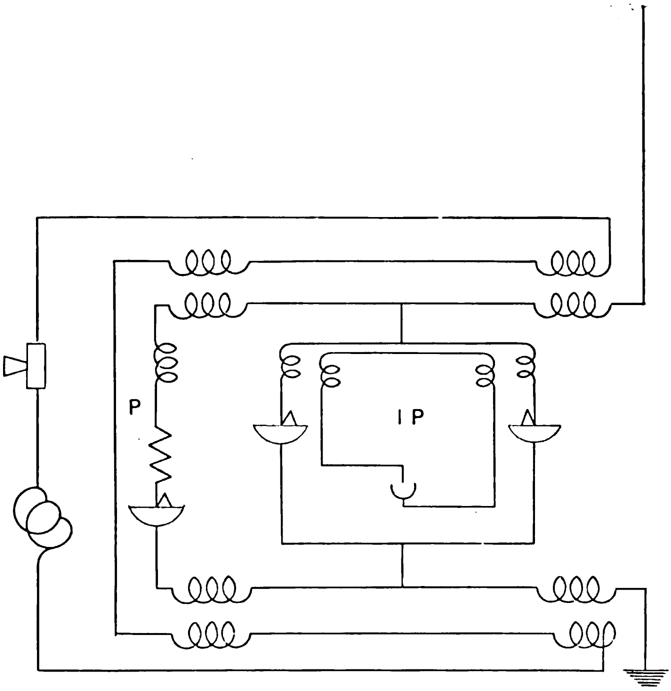


Fig. 29.

---

[1] This method may, of course, be used for duplex working in wireless telegraphy. As some question has been raised in regard to the capacity of wireless telegraph lines the writer would say that he has received messages at the rate of 250 words per minute by wireless and is now experimenting with apparatus designed to give 500 words per minute. With duplexing this gives 1,000 words per minute or 60,000 words per hour. The manager of one of the largest cable companies has stated (*London Daily Mail*, Sept. 24, 1907) that all the Trans-Atlantic cables together send 24,000 words per hour. It would appear, therefore, that

6. *Receiving station relay.* The receiving station relay is similar to the transmitting relay shown in Fig. 16. The same remarks apply to its use in connection with wire lines as to the transmitting relay.

F. OPERATION

As will be realized from the above, the operation of a wireless telephone system is very simple. The operator merely throws his switch to the position for telephoning and talks into an ordinary transmitter and listens in an ordinary telephone receiver. When the duplex method is used, as is always advisable, the conversation proceeds exactly as over an ordinary telephone line. Fig. F shows a phonograph transmitting music and speech wirelessly. Fig. G shows talking by relays from a local circuit.

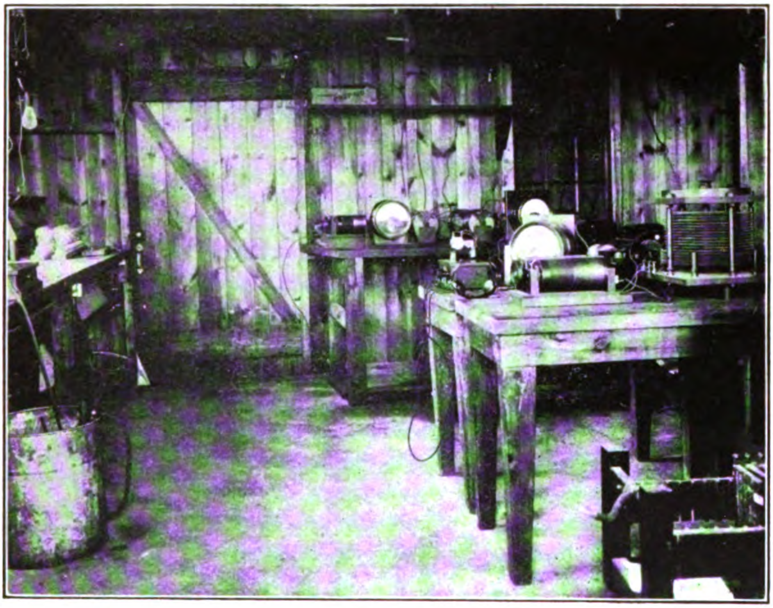


FIG. H.

---

if capacity alone be considered a single station on each side of the Atlantic can handle more traffic than all the present cables. It should be pointed out, however, that the mere ability to handle the messages is not sufficient and that unless the wireless telegraph companies obtain land facilities equal to those at present enjoyed by the cable companies they cannot handle the traffic as efficiency, *i.e.*, cannot deliver a message from New York to an individual in London and receive a reply in the same time. Fig. K shows a Wheatstone transmitter used for the test referred to.

I believe I am correct in saying that the transmission by wireless telephone is considerably more distinct than by wire line and that the fine inflections of the voice are brought out much better. This, I presume, is due to the fact that there is no electrostatic capacity to distort the speech, as in the case of wire lines, though I think the effect is also partly due to the absence of telephone induction coils with iron cores. Possibly some of the gentlemen present have witnessed the operation of the wireless telephone transmission between Brant Rock and Plymouth and between Brant Rock and Brooklyn. If so I think they will bear me out in saying that the transmission was clearer than over wire lines.

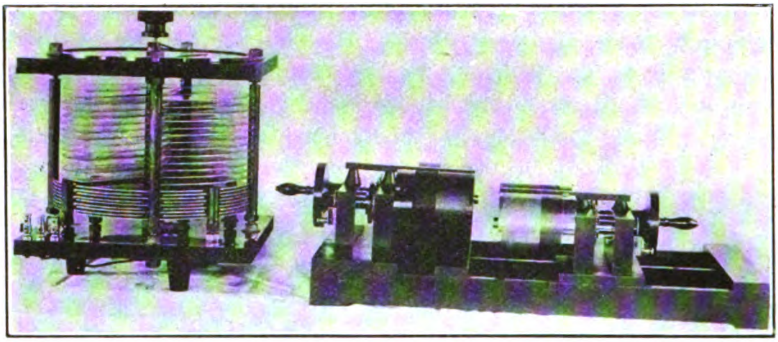


Fig. I.

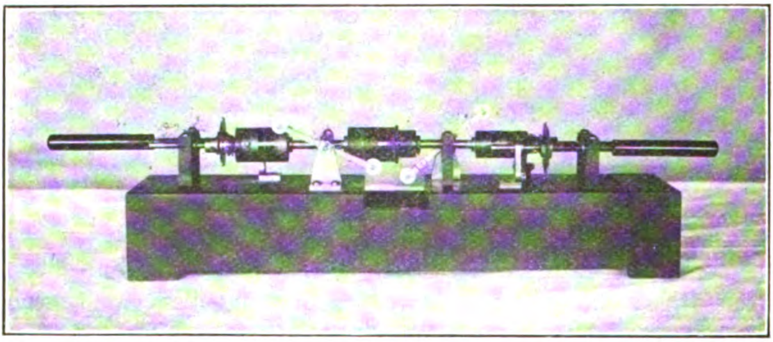


Fig. J.

As a rule, there is absolute silence in the wireless telephone receiver except when talking is going on, though of course the usual noises may be heard if persons are walking across the room, etc. This makes listening in less of a strain than when talking over wire line. Even during severe atmospheric disturbances the talking is not interfered with to any noticeable extent, provided of course that an interference preventer is used.

A comparative test was made with talking between Brant Rock and Brooklyn by wireless and by wire telephony. The talking over the wire line was done from a long distance station in Brooklyn. The wireless transmission was considerably the better. The fact that the wire line included in its circuits a cable from New York to Brooklyn was of course a disadvantage, but even allowing for this, practice and theory appear to be in agreement to the effect that transmission by wireless telephony over long distances is better than by wire line.

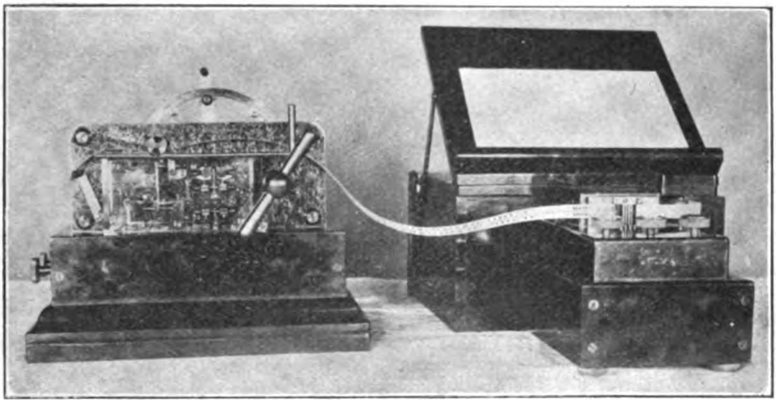


Fig. K.

This method should be of especial value to independent telephone companies, which have their local exchanges, but no long distance lines, especially since no franchises or rights of way are necessary.

G. Possibilities

A. *Local exchanges.* There is no immediate prospect that wireless telephony will take the place of local exchanges. The difficulty in regard to the number of tunes can be overcome, but the fact remains that high frequency oscillations cannot be transmitted over wire and hence each subscriber must have his own generating station. At the present time no method is known which would be practical if placed in the hands of a subscriber. If such means should be found it would be very

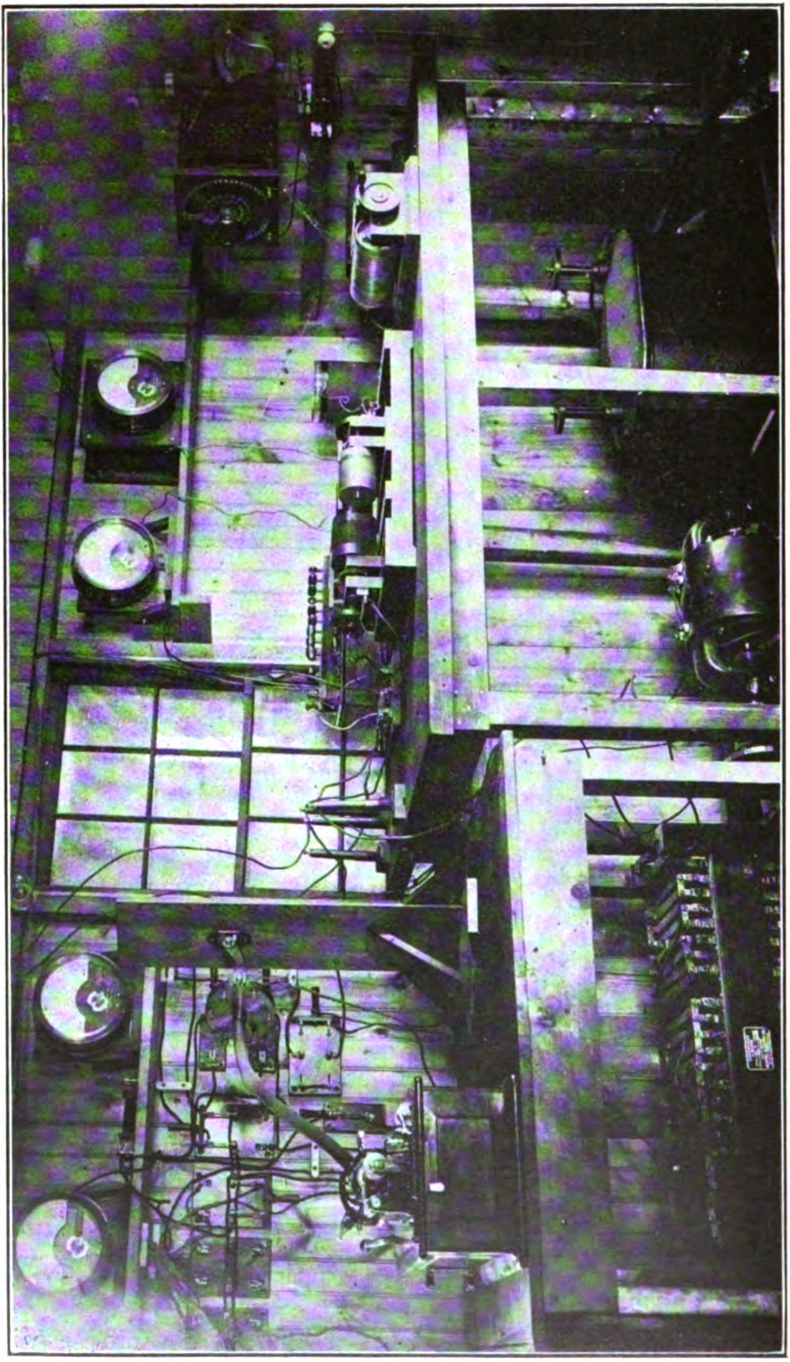


Fig. F.

convenient to call up directly instead of through an exchange, but as I see it there are no immediate prospects of this.

B. *Long-distance lines.* I believe, however, that there is a field for wireless telephony for long distance lines. The present long distance lines are very expensive to construct and to maintain, and a storm extending over any considerable section of country inflicts considerable loss on the telephone companies. Moreover, the distance of transmission is limited by the electrostatic capacity of the line, as I understand it. Wireless telephony would have the following advantages.

1. The initial cost would be very much less than that of wire lines.

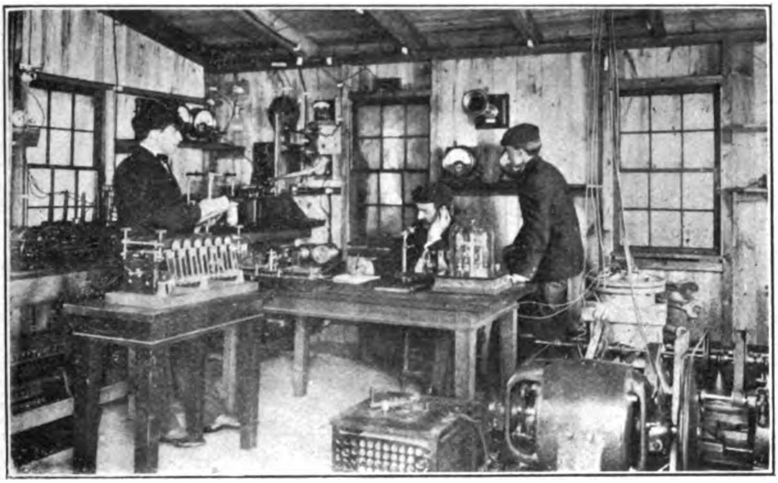


Fig. G.

2. The maintenance would be practically negligible in comparison.

3. In case of any breakdown, it would be right in the station and not at some unknown point outside on the line.

4. The depreciation would be comparatively small.

5. The number of employees required would be smaller.

6. The transmission is better, and as there is no distortion of the speech, the working distance is, it is believed, considerably greater.

7. The flexibility is greater. With wire lines a telephone company may not be able to give a Boston subscriber a line to New

York, while having lines from Boston to Chicago and from Chicago to New York free. Operating wirelessly the wireless circuit normally used for operating between New York and Chicago and between Boston and Chicago could be used to operate from Boston to New York.

8. No right of way need be purchased and franchises it is believed, are not necessary.

It will be noted that I have carefully avoided mentioning any of the disadvantages of wireless telephony for long distance work. I presume this is because I am not a telephone engineer. I hope the defects will be supplied by the experts who are familiar with telephone operation and therefore better able to point out the defects. Before leaving this part of the subject I would say that I think the question of interference has been worked out to such an extent that no serious difficulty need be feared in that direction.

C. *Transmarine Transmission.* Wireless telephony is peculiarly suited for this class of work. Pupin's ingenious and beautiful method has been successful at Lake Constance, Switzerland, I believe, but even assuming that deep-sea cables of this type could be laid and operated successfully, they would nevertheless be very much more expensive than wireless telephone stations. It is believed that wireless telephony will come into extended use for this purpose. Even without further development telephonic communication could be established between Norway or Denmark or Germany or Spain and Great Britain; between Sardinia and Corsica and France and Italy; between France and Algeria, between Australia and Tasmania and New Zealand; between the United States and Cuba and Porto Rico, etc, were it not that it is at present forbidden by law.

As regards telephonic communication between England and America, my measurements show that this should be possible with an expenditure of approximately ten kilowatts and suitably large towers say 600 feet high, or with some of the new forms of antenna. Whether such a transmission would be commercially valuable or not is another matter. Personally I do not see that it would, but when I remember that at the time when the telephone was first being introduced a number of eminent business men decided that the house-to-house printing telegraph would be more of a success commercially than the telephone for the reason that no one would want to do business unless he were able to have a record of the transaction, I must admit that there is a possibility of my being mistaken in this.

D. *Wireless telephony from ship to ship.* Here, of course, wireless telephony occupies a unique position. Wireless telegraphy has the disadvantage that a telegraph operator must be carried. The additional expense is an objection in many cases. The proposition that the captain or mate should also be a telegraph operator has not met with favor. Anybody, however, can operate the wireless telephone and almost every vessel carries an engineer capable of repairing the electrical apparatus in case of accident. The final arrangement will, I believe, (if we can prevent the governments from carrying out their proposed laws, forbidding wireless telephony), be this; that passenger vessels will carry a telegraph operator and use the telephoning apparatus for ordinary work and for telegraphing where it is desired to communicate over long distances. Other vessels will use the telephone alone.

E. *Wireless telephone from ship to local exchange.* This also will, I think, have considerable value, as enabling the captain of a vessel to communicate, by relaying over the wire line, with the owner of the ship, or enabling a passenger on a vessel to communicate with friends on shore.

F. *Range of wireless telephony.* 1. *Atmospheric absorption.* The great obstacle to long distance wireless telegraphy and telephony is atmospheric absorption. For short distances up to 100 miles in the Temperate Zone there is little difference between the strength of the signals at one time of the day and another. As soon as the distance is increased much over 100 miles for the Temperate Zones and 40 or 50 miles for the Tropics the signals at night are very irregular and there is great absorption during the day time. The daylight absorption may be so great that less than a tenth of one per cent. of the energy transmitted gets through. Some nights will be as bad as day-time while on other nights there will be apparently no absorption.

Fig. 30 is a curve showing the strength of the messages transmitted between Brant Rock, Mass., and Machrihanish, Scotland, at night, during January, 1906. Nothing at all was received that month during daytime.

The change in the strength of the signals is very sudden. In working from Brant Rock to Porto Rico, a distance of 1700 miles, the strength of the signals with short wave lengths would fall off to one one-thousandth of their former value during a period of less than fifteen minutes, while the sun was rising.

Early experiments showed that the absorption was greater as the wave length was increased and the effect was at first attributed to absorption in the neighborhood of the sending station, and was thought to increase continuously with the wave length.[1] This fluctuating absorption at one time appeared to place a fundamental obstacle to commercial wireless telegraphy, as telegraph engineers will easily appreciate the impossibility of operating telegraph systems with circuits where the strength of the received signals may fall to one thousandth of its value or rise to a thousand times its value in the course of a few minutes.

It was therefore considered absolutely essential, in order to decide whether long distance wireless telegraphy was commercially possible or not, to investigate this phenomenon fully. As a preliminary the station at Brant Rock sent to four or five other stations at varying distances and comparative readings were taken. The following table shows the general character of the results obtained:

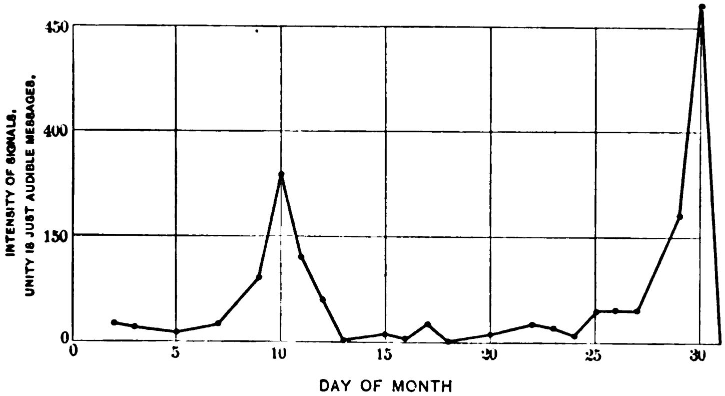


FIG. 30.—Curve showing variation of intensity of transatlantic messages for the month of January, 1906

---

[1] A mathematical explanation of this supposed fact was given by Dr. Fleming "Principles of Electric Waves Telegraphy" pages 617–618, 1906, the following conclusions being reached:

"Accordingly, the chief part of the weakening of the wave by sunlight is done in the neighborhood of the sending antenna, where the magnetic force *H* is greatest, and it is more sensible for long and powerful waves than for short and feeble ones. This agrees with the observations of Mr. Marconi".

Station	Distance	Strength of signals received on worst nights (strength of unabsorbed signals being taken as 1000).
Company's cottage	200 yards	1000
Lynn	30 miles	1000
Schenectady	170 miles	500
Philadelphia	270 miles	300
Washington	400 miles	150
Machrihanish	3000 miles	1

These experiments proved conclusively that the absorption did not take place in the neighborhood of the sending station, because the strength of the signals received at nearby stations was the same during the day as during the night while there was great variation in the strength of signals received at stations further away.

It was also found that the absorption at a given instant was a function of the direction as well as of the distance, since on a given night the signals received by stations in one direction would be greatly weakened, while there would be less weakening of the signals received by stations lying in another direction, while a few hours or a few minutes later the reverse would be the case.

This was thought to be connected with the coming weather conditions but before this fact is proved a much larger amount of data must be collected. Through the kindness of the U. S. Weather Bureau I was enabled to obtain a chart of the magnetic variations and on comparison of these with the absorption between the Massachusetts and Scotland stations there appeared to be a quite definite relation, *i.e.*, the greater the absorption the greater the magnetic variation. Here also, however, much more data is needed before arriving at a definite conclusion. The fact that the absorption did not take place in the neighborhood of the sending station having thus been definitely settled the next point to be investigated was whether or not there was any way of overcoming it.

The fact that variations in the absorption occurred with extreme rapidity, the absorption increasing sometimes a hundred fold in a single minute, and at night, when the effect could not be due to the sun directly, seemed to indicate that the body producing the absorption, whatever it was, was not in a state of continuity but was broken up into masses like clouds.[1] This also was in accordance with some experiments made in Brazil in 1905.

---

[1] *Electrical Review*, May 18, 1906.

From optical theories it is known that where the absorption is produced by conducting masses of a more or less definite size the absorption is to a certain extent selective. The next point in the investigation was, therefore, to determine whether there was any possibility of this being the fact in the case of the absorption of wireless signals.

Comparative tests were therefore made of the absorption at night and during the day between Brant Rock and Washington, with wave lengths varying from a fraction of a mile up to four or five miles. It was found that the absorption did not increase continuously with the wave length but reached a maximum and then fell off with great suddenness.

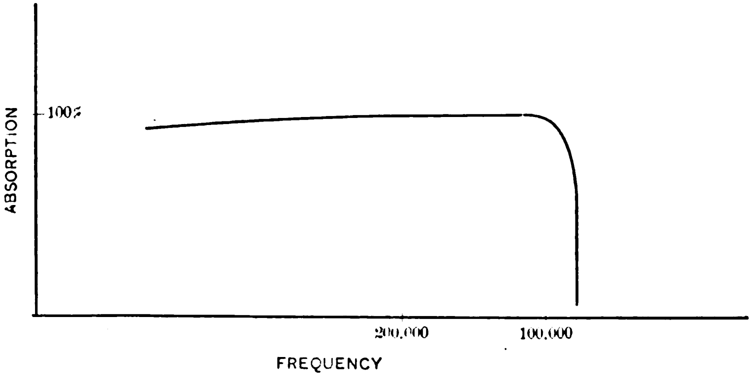


Fig.31

Fig. 31 shows the general character of the curve, the ordinates referring to the amount of the absorption and the abscissas to the wave frequency.

It may be noted that the absorption is a maximum at a frequency of about 200,000 per second, nine hundred and ninety nine thousandths (0.999) of the energy being absorbed at this frequency during daylight, while for a frequency of 50,000 the absorption does not appear to be appreciable. Longer experiments, of course, might show some absorption, but in any case it is of a different order from the absorption for the shorter wave lengths.

Experiments were then made between Brant Rock and the West Indies, a distance of 1700 miles, during the spring and summer of 1907. It was found that the results were of the same character, *i.e.* that while there was greater absorption for frequencies of 200,000 there was comparatively little absorption for frequencies in the neighborhood of 80,000 and messages were successfully transmitted in daylight with this latter frequency. No messages were received in daylight with the higher frequency, though messages transmitted from the same station and with the same power and frequency were officially reported as having been received at Alexandria, Egypt, a distance of approximately 4000 miles.

The fact that these experiments were made during summer weather, and the receiving station was in the Tropics, and the fact that the distance, 1700 miles, was practically the same as that between Ireland and Newfoundland definitely settled the question as to whether long distance wireless telegraphy was a commercial possibility or not and the results were therefore published.[1]

Since the publication of the above results transmission has been accomplished by means of these long waves over still greater distances during daylight. Sig. Marconi early in October, 1907, succeeded in operating between Glace Bay, Nova Scotia, and Clifden, Ireland a distance of more than 2000 miles, at a frequency of approximately 70,000. The same messages were received at Brant Rock, Mass., a distance of nearly 3000 miles.

Still more recently Captain Hogg of the "Glacier" has written that during the southward passage of the Pacific fleet he received messages from the station at Brant Rock, Mass., while off Cape Ste. Roque, Brazil, S. A. The frequency used for sending was approximately 80,000, and the messages were received with the very interesting and sensitive silicon receiver invented by Mr. Pickard. This distance of 3000 miles is the greatest yet achieved by wireless transmission during daylight and would indicate that with the use of suitably high towers much longer distances can be reached.

2. *Range of wireless telephony and wireless telegraphy compared.* For the same power it is possible to telegraph to a further distance than to telephone. Distinct speech depends upon the presence of harmonics of a frequency as high as 1200 per second. The amplitude of these harmonics is according to some rough experiments made by the writer only about one per cent. of the fundamental frequency. Consequently, with a per-

---

[1] *The Electrician* (London), July 26, 1907.

fectly modulated transmitter 100 times as much energy would be necessary to telephone a given distance as to telegraph. It fortunately happens, however, that a carbon transmitter and also the circuits in which it is used, can be so constructed as not to modulate perfectly but can be arranged so as to accent the higher harmonics.

With transmitters arranged for the purpose good transmission has been obtained with thirty times the energy required to produce audible telegraphic signals. By still further modification the power required has been reduced to approximately ten times that necessary for telegraphing, curiously enough without noticeably distorting the character of the speech. There is one fact, however, which prevents the ratio from being as large practically as the instruments show, *i.e.*, speech can be satisfactorily understood with a less increase of power above a minimum audibility than telegraphic signals.

The amount of power necessary for wireless telephony may therefore be taken as approximately five to fifteen times that necessary for wireless telegraphy; *i.e.*, under the same circumstances and for the same power the wireless telegraph will carry two to four times as far. The difference in range would be very much greater also but for the curious fact that there is much less falling off with sustained oscillations than with intermittent groups of waves, even though the frequencies are identical.

This fact has been repeatedly determined by sending between Brant Rock and Brooklyn on the same frequency, using in the one case spark produced trains of waves and in the other the high frequency dynamo. The difference in the falling off for the same frequency and energy is very great but further work is necessary before anything very definite can be said about it or the reasons finally determined.

H. How Wireless Telegraphy has been Throttled by Governmental Action

The question has been asked why, if wireless telegraphy can compete with wire lines and cables, it is not put into operation. This is not an unnatural question. Ninety nine individuals out of a hundred would probably consider that if an inventor had perfected a system of wireless telegraphy or telephony so that it would operate reliably over long distances and would handle messages at a fraction of the cost of the present cables and without interfering with other stations, he would immediately pick out from an atlas half a dozen suitable points for operation, such as from France to Algiers, Italy to Egypt, Great Britain to Germany, New Zealand to Australia, Australia to Hong Kong, or Canada to Great Britain, and immediately commence commercial work, being perhaps delayed a few weeks on account of some slight formalities in connection with obtaining permits. The statement that nothing of the sort could be done would be received with incredulity, especially if it were known that the business men who would benefit by the proposed transmissions were strongly desirous of having them put into operation.

This is a very important matter, not because the crushing out of a new system of telegraphy is so very important in itself, but because the prospects are that other branches of the electrical profession may have to face the same situation in the near future and it is, therefore, advisable to show in some detail just what governmental ownership means in its relation to the progress of civilization. I will, therefore, explain fully, but as briefly as possible how commercial wireless telegraphy is hindered by governmental action.

Examination of a chart of the world immediately suggests a number of points as suitable for the installation of wireless communication. For example the following:

1.	United States	to	Cuba.
2.	“ “	“	Porto Rico.
3.	“ “	“	Jamaica and other West Indian Islands.
4.	“ “	“	Bermuda.
5.	“ “	“	Newfoundland.
6.	“ “	“	Great Britain.
7.	“ “	“	France.
8.	“ “	“	Azores.
9.	Newfoundland	“	Great Britain.
10.	Great Britain	“	Ireland.
11.	“ “	“	France.
12.	“ “	“	Spain.
13.	“ “	“	Germany.
14.	“ “	“	Denmark.
15.	“ “	“	Norway.
16.	France	“	Algiers.
17.	Italy	“	Egypt.
18.	New Zealand	“	Australia.
19.	Australia	“	Hong Kong.

The first fact to be noted is that these countries with the exception of Porto Rico are foreign countries and that in practically every one of these, Porto Rico is believed to be the only exception, there are stringent laws in force forbidding the erection of wireless stations without permits. The difficulty of obtaining these permits is shown by the fact that one wireless company within the writer's knowledge has been endeavoring for more than four years to obtain permits in the majority of the above mentioned foreign countries and has so far succeeded in obtaining only one permit and that for direct communication between the United States and Great Britain.

To take a specific illustration. In 1903 an American company was requested to install communication between Bermuda and the United States. The principal industry of Bermuda is the growing of produce of various kinds, which is exported almost entirely to the United States. The only present means of communicating is through Nova Scotia, and in winter especially, owing to the delays on the land lines, the service is often quite insufficient. Permission was asked of the Home Government by the Bermudian incorporators, but without success.

A petition was then signed by virtually every prominent business man in the islands and forwarded to the Home Government. The members of the New York Produce Exchange drew up a petition and forwarded it to the Secretary of State requesting him to use his influence in the matter. The Colonial Office stated in reply that it was favorable to the project but that the matter must be referred to other branches.

The Bermudian business men also sent several representatives to Great Britain to urge personally the granting of the permit. After a lapse of several years a definite reply was received to the effect that the permit would not be granted. The Bermudians then took up the matter through a Canadian company which sent several representatives to interview the authorities in Great Britain but without success. The Lord High Commissioner of Canada, Lord Strathcona, finally was kind enough to interest himself in the matter and personally presented the case before the British authorities. It is hoped by the Canadian company and the Bermudians that the permit will finally be granted, but this specific illustration will explain the difficulty in obtaining permits for operation.

As illustrating a different obstacle the case of Newfoundland may be taken. This is the natural point for establishing communication with Great Britain and the experiments previously referred to as having been made between Massachusetts and the West Indies showed conclusively that there would be absolutely no difficulty in operating commercially and with ease over this distance. On the other hand to operate directly from America is a much more difficult proposition for the reason that, as examination of a great circle chart will show, the whole of Newfoundland and Nova Scotia lies between any point in the United States north of Hatteras, and Great Britain.

If operation in Newfoundland were not forbidden by law half a dozen wireless stations would be at once erected, and the companies would be only too glad to pay into the Newfoundland treasury the ten or twenty thousand dollars per annum to be collected if they were put on the same footing as the cable companies in order to save the cost of the longer transmission. The Newfoundland government a number of years ago granted a monopoly of wireless telegraphy to one company, which company has never erected a transatlantic station in that island. While this monopoly has been very injurious to Newfoundland, on account of the loss of revenue entailed, it has been still more so to the wireless companies and to the public at large, which otherwise would have had cheap transatlantic telegraphy several years ago.

Another very formidable obstacle is the fact that in practically all the foreign countries referred to (and in Porto Rico) land telegraphy is a government monopoly. Consequently, the wireless companies are entirely at the mercy of the government, are barred from collecting their own messages and must pay whatever tolls are fixed by the various governments. This, of course, also operates to prevent rapid service, since instead of communicating directly from Paris to London the messages would have to be sent from Paris by wire line to the French wireless station thence to the English wireless station and thence again by wire to London.

In a number of countries, the cable lines are also owned by their governments which makes them naturally averse to losing the invested capital or to permiting private companies to compete. It would be evident therefore that no matter to what perfection the art of wireless telegraphy is brought, years will elapse and the exercise of a great deal of political influence will be necessary before the public gets the advantages of the cheaper rates.

Ship communication. Here again the development of wireless working has been stifled by legislation. Vessel owners were at first rather slow to take up the matter of equipping their ships but after the system had proved its worth in several cases and some of the owners had had to pay large sums for salvage in cases where a wireless installation would have avoided the loss, its value began to be realized. It was at this point that the governments again stepped in with premature and injurious legislation. As a specific illustration, a United States company had arranged with the owners of some two hundred vessels to construct a line of stations from Maine to Texas, to operate with stations installed on the ships. The announcement was made that the administration proposed to recommend to Congress that wireless telegraphy be made a government monopoly.

A representative of the wireless company requested permission to submit some evidence to the effect that such a government monopoly was not necessary and that the various stations could operate without interference. A reply was received from the Administration that " information in regard to the subject was not desired ", and the administration recommended that wireless communication with ships should be made a government monopoly.[1]

It was proposed to carry this out as follows:

1. To establish Navy wireless stations at points along the coast where wireless stations were needed by the merchant marine.[2-4]
2. To forbid the operation of private stations at these points.[4]

---

[1] Recommendations of the Inter-departmental Board on Wireless Telegraph, 1904 submitted and approved by the Administration.

[2] *Ibid.* " That the maintenance of a complete coastwise system of wireless telegraphy by the Navy Department is necessary for an efficient and economical management of the fleets of the United States in time of peace and their efficient maneuvering in time of war. "

[3] *Ibid.* " As fast as the naval wireless telegraph stations are in operation the Navy Department shall receive and transmit through these stations free of charge all wireless messages to and from ships, providing such stations do not come in competition with commercial stations, until such time as Congress may enact the necessary legislation governing this subject ". That the statement in regard to competition is disingenuous will be seen from examining the following extra Note 4, since only one station, and that a Navy one would be permitted at points where there was merchant marine business.

[4] *Ibid.* " In asking for legislation on this point the board invites attention to the fact that where wireless stations are needed for the merchant marine, as a rule, the navy will also require them. The board believes it to be in the interest not only of governmental but of public

3. The Navy stations are to handle all messages to and from ships free of charge.

4. Wireless companies to be permitted, after obtaining a license from the Department of Commerce and Labor, to erect stations at points where there was no merchant marine business.[5]

The official approval and transmission of these recommendations by the Administration, although they were opposed and never went into effect, terminated, of course, all negotiations with vessel owners, since the owners would naturally not agree to contract for the transmission of their messages with the immediate prospect in view that the Government would transmit them free of charge. At the present time the masts ordered for the proposed line of stations are rotting at various points along the seaboard and the apparatus purchased for installation is deteriorating in storage.

The development of ship communication had just begun to recover from this blow when an International Wireless Telegraph Conference was arranged for by the various governments. In America no opportunity was afforded the wireless companies of presenting the case to the delegates to the Conference, and a very stringent set of regulations was adopted. The Administration transmitted these regulations to the Senate.[6] The ratification of the treaty embodying these regulations was opposed by the Marconi Co., and by the National Electric Signaling Co. The following facts were pointed out:

1. That the proposed regulations virtually amounted to confiscation of the property of the wireless companies; that the working at present was carried on at a loss; that no wireless company was at the present time paying dividends; that the proposed rates would not permit of any return on the capital invested; and that the regulations would so limit the amount of business which it would be possible to transact that it would not pay to keep up the stations.

2. That the inventors in the art of wireless telegraphy had

---

economy and efficiency to permit the naval stations to handle the public service, for in the present state of the art but one station is desirable for the public interest in such places. It is admitted that there may be special cases where private stations can serve a useful purpose and the board believes that the Department of Commerce and Labor should have the duty of issuing licenses in such cases under such regulations as will prevent interference with stations necessary to the national defence."

[5] *Ibid.*

[6] Senate Document, Sixtieth Congress, first session.

expended large sums of money in developing their systems, and such confiscation was therefore unjust and was thought to be unconstitutional.

3. That the regulations were impracticable in the following respects:

a. By requiring ships to use two tunes only[1] all stations were placed, so to speak, on two-party lines, thereby producing a maximum of interference and preventing any one station working while any other was operating.

b. Allowing only five minutes per message and assuming only ten ships each with ten messages to be in the neighborhood of a given seaport, more than eight hours would have to elapse before the last station had transmitted its message. This time is believed to be underestimated, as the regulations provide that each ship before sending its message must call the coastwise station, have a number assigned to it, inform the coast station of its distance, its true bearing in degress, its true course in degrees, its speed in nautical miles, the number of words it has to transmit; must be informed how long it will have to wait, whether the transmission is to be in alternate order or in series, interrupt the sending after each 20 words, send an interrogation mark, wait for repetition of the last word, etc.[2] Hence it would be rather difficult to maintain the average time mentioned. This excessive delay would cut down the traffic to such an extent as to render it impossible for the stations to pay expenses of maintainance, and any telegraphic engineer will appreciate the difficulty of carrying on commercial business under such regulations.

c. Placing all vessels on two-party lines introduces all the difficulties of the party line method and loses the only advantage, as it might easily happen that a ship in distress using one frequency might be within range of a number of vessels using the other frequency, but outside of range of any vessel using its own frequency. The obvious and practical method is legally to establish a single tune to be used exclusively for calling and distress signals but not for any other purpose; the transmission of messages to be continued by switching over to other tunes once the call has been received and accepted. In this way a ship in distress can always be sure of calling any vessel within range, while the transmission of messages can be carried on without interference and without one ship having to wait until the other is finished.

---

[1] Regulations II and III.

[2] Regulations 19 to 26.

4. Its restrictions are of such a character as to prevent the future development of wireless telegraphy. For example.

a. The regulation[1] that all stations must carry a licensed wireless telegraph operator capable of receiving at twenty words per minute would prevent the installation of wireless stations on board the majority of ships since only the larger vessels can afford the additional expense of the operator. Many vessels would install wireless telephones which do not require a skilled telegraph operator, if it were not for this regulation.

b. The rules forbidding[2] the transmission of telegrams calling for repetition of messages, or for acknowledgement of receipt, or for telegrams to be forwarded, or for telegrams to be delivered by express or by mail, or for the transmission of money-order telegrams or for the transmission of telegrams with answer prepaid, or for the transmission of urgent telegrams are especially restrictive. By forbidding the transmission of telegrams of all the above classes the commercial field of wireless telegraphy is limited to such an extent as to deprive wireless telegraphy of its chief value.

5. It expressly forbids the use of a number of the most important developments in wireless telegraphy. For example.

a. Section 3 in effect forbids long distance transmission in daylight. This section states that ships must not use wave lengths exceeding 600 meters. It is now well known that daylight absorption is very great for these wave lengths and that much longer wave lengths must be used during daytime. This rule therefore virtually forbids wireless telegraphy during daylight except within a very limited radius, and in case of an explosion or fire on shipboard during daylight the vessel would be unable to summon assistance unless by some fortunate chance another vessel happened to be within the radius limited by the restriction to the short wave length. It also virtually prohibits ships keeping in communication with the shore for more than twelve hours out of twenty-four.

b. Section 3 states that the system employed must be a syntonized system, thus forbidding the use of systems such as the heterodyne system which do not depend for selectivity on syntony. This would not be so injurious if it were not for the fact that the present indications are that syntony will in the near future be abandoned as a means of obtaining selectivity.

---

[1] Section 6, paragraph III.

[2] Section XXXIII.

c. The rules of Section 2, 3, and 18 to 26, virtually forbid the use of duplex and multiplex systems. There is no reason why a number of ships should not communicate with the same station simultaneously, but the above rules forbid this by requiring only two wave lengths to be used and the messages to be taken one after the other.

d. It is premature. The expression " that an art " is in its infancy is a very hackneyed one but if it can be applied properly to any art it is to wireless telegraphy. The fact that the proposed regulations are unsuitable does not reflect in any way on the ability or conscientiousness of the delegates, though it would seem that it would have been advisable to consult the engineers of the various wireless telegraph companies before drafting the rules. The main difficulty, however, is that no one, no matter what his knowledge of the present state of the art, can foresee the future developments. The question of wave length and daylight absorption is an illustration of this, as is also the question of syntonized circuits. The time has not yet come for any such hard and fixed regulations as thus proposed.

6. It was also pointed out that the public had no rights in regard to wireless telegraphy, since a patent differs from a franchise in that when the public grants a franchise it gives a right in respect to something which already exists and which it owns, and it therefore has a right to make what stipulation it chooses. In the case of a patent, however, the right is not given in respect to something which the public owns, but in regard to a new creation which exists merely in the mind of the inventor, to be called into being or not at the inventor's will, and therefore a thing in which the public has no right except as it obtains one by stipulation with the inventor. In the case of wireless telegraphy the companies invested their money under the patent law contracts with the various governments, and therefore the inforcement of regulations of the character proposed without the consent of the inventors is a breach of contract.

As a result of the hearing and of representations supporting the position of the wireless companies made by a very eminent electrical engineer the Senate Committee has decided to do nothing for the present in the matter. During the hearing the fact was brought out by the committee that the proposed regulations were passed upon the assumption that interference could not be kept out, and that the U. S. Navy had already made official reports on tests of interference preventers which showed that this was not the fact. On direct question by the Senate Committee the representative of the U. S. Navy present at the hearing freely admitted that it was a fact that interference could be kept out.

Still more recently another set of recommendations has been forwarded by the Administration to the Senate endorsing the recommendation of the Secretary of the Navy that a law should be passed[1] making it an offence punishable by imprisonment for one year of a fine of $2,000 or both for a private station to continue sending when called upon to discontinue by a Navy operator, or to produce interference with a Navy station when the latter is transmitting an official message. This recommendation was not accompanied by any recommendation to the effect that the Navy stations should use any means for keeping out interference. Before the transmission of this recommendation a conference was sought with the Navy officials with a view to drafting a form of regulation which would accomplish the results sought, without placing the wireless companies at the mercy of the Government and without virtually confiscating their property but it was found impossible to obtain a hearing.[2]

The following memorandum of a portion of the interview between Secretary Straus of the Department of Commerce and Labor and the representative of the wireless company, asking for a hearing, will be of interest:

REPRESENTATIVE: "Will you not, Mr. Secretary, be willing to assist us in obtaining a treaty which, while giving the government all it desires in the way of intercommunication between different systems, reservation of wave-lengths for government purposes, etc., will, at the same time, avoid driving the wireless companies into bankruptcy?"

SECRETARY STRAUS: "The treaty was reported by the experts of the government departments, and we propose to carry it out, as it is the policy of the administration."

REPRESENTATIVE: "But, Mr. Secretary, these regulations virtually prevent the wireless companies from doing any commercial business. With everybody on one party line, even without the numerous other restrictions, it will not be possible to handle a sufficient number of messages to pay operating expenses, and the companies will necessarily be driven into bankruptcy."

---

[1] *Congressional Record*, Feb. 14, 1908. Also H. R. bill 17719, 60th Congress, 1st Session.

[2] See also appendix.

SECRETARY STRAUS: " That has nothing to do with this department. If you are injured you should go to the Congress and ask them to reimburse you."

REPRESENTATIVE: " Mr. Secretary, you know that it would be practically impossible to get a bill to reimburse a private company through the Congress. Why should the government crush out a new and important method of communicating which will save the country millions of dollars yearly, when the government will gain nothing by the action. We feel that your department ought to assist us in this matter."

SECRETARY STRAUS: " It has been decided by the administration that the treaty should be approved as it stands."

It will be noted that this conversation took place in the United States, and not in Russia, as might possibly be otherwise inferred. It will appear from this and the experience of others that the original object of the formation of the different government departments has been rather lost sight of in recent years.

It will perhaps be seen that the difficulties in the development of wireless telegraphy have not been wholly of a technical nature and more patience may perhaps in the future be extended to those engaged in the work.

CONSIDERATIONS

The subject is, however, one which is bound to concern in the near future other branches of the engineering profession than those now affected and the present appears to be a suitable time for considering the matter more broadly.

Whatever the ultimate object of man's existence may be it is tolerably certain that it is not to occupy his entire mental activity with the question of how many grubs he can secure for food and where he can find a suitable hollow tree in which to spend the night. But whatever we have above this is due solely to the inventor (in which term I include not only the men who discovered how to produce fire and to build houses and steam engines and alternating current motors, and therefore all engineers whether they take out patents or not, but also those who discover how to distribute what is created in such a way as to make it available).

In the state of nature which Tolstoy so greatly lauds and so carefully avoids advance is impossible; all available energy of mind and body is necessarily employed in the problem of maintaining a bare existence. Before we can advance toward our goal, whatever it is, we must first have time and opportunity and a means of maintaining any advance. That we have this time and opportunity is due to the fact that by means of innumerable inventions we are rendered every day less dependent upon the accidents of nature. It would therefore appear, that whatever our ultimate goal may be, the first essential for reaching it is an increased control over the forces of nature.

This increased control can only be obtained through intense effort. When we see a performer at a circus contorting his body into apparently impossible positions we realize the peculiar aptitude and the many years of training which must have been necessary. It is not generally realized, however, that a still more peculiar aptitude and many more years of still more intense training are necessary for those who would do useful work in any branch of mental achievement. We seldom think, in reading a mathematical paper for example, that the author has studied possibly for an average of ten or twelve hours a day for twenty or forty years before achieving sufficient proficiency in his subject to be able to accomplish the work.

To obtain results in a special line therefore a man with special aptitude and training is required. In addition to this there must be the opportunity. Hundreds of thousands, and in many cases millions of dollars are necessary for the development of an important invention. Such sums will not be furnished if there is no prospect of a return. As the success of an invention is always doubtful, the return from a successful invention must be sufficient to cover the losses from the much larger number of failures, for if the average return from one hundred inventions falls below that obtainable from mortgages or other forms of secure investment there will be no incentive.

The following question seem to me to be worthy of consideration:

1. Whether public officials, elected by the people, would consider themselves justified in expending millions of dollars on the development of inventions the success of which was uncertain.

2. Whether the best men to develop such inventions successfully would be found among the Government officials available.

3. Whether development can be expected in an art or industry entirely under Government control or ownership.

4. Whether universal Government control or ownership does not necessarily involve a fixed and non-progressive state as opposed to a state of progress and development.

APPENDIX

In the United States some additional hindrances on the part of the Government have been met with. For example, in the United States, and in Russia, as well, an inventor has no legal remedy in case the Government appropriates his invention.[1] It might be thought that the inventor could protect himself by suing infringing companies, but this is not so.

The wireless sets originally used by the United States Navy were imported from a country which was not at that time under the Patent Convention, and as they were purchased abroad no action could be taken. The then Secretary of the Navy, Mr. Moody, refused to require the foreign company to appoint a responsible representative in America. It was not until some years later, when, Mr. Morton being Secretary and the matter having been taken up by one of the Senators, this was done, and an injunction was obtained against the representative so appointed.

On further protest the next Secretary of the Navy, Mr. Bonaparte, stated that the patents could not be recognized as they had not been sustained. He was again approached but said that he had decided that he was not bound to respect them as he considered the price too high.[2] He declined, however, to allow the price to be fixed by arbitration, stating that he considered that the price should be fixed with reference to the cost of manufacture solely. The principal infringing companies having been enjoined the Navy and Army began manufacturing the devices themselves in quantities.

Through the influence of one of the Senators the matter was again taken up and it was arranged that the Secretary of the Navy, Mr. Bonaparte, should obtain a legal opinion from the Attorney-General in regard to the matter. This opinion was prepared by one of the Attorney-General's assistants and proved to sustain the claims of the wireless company on every point. Before it was finally transmitted the Secretary of the Navy, Mr. Bonaparte, withdrew his request for an opinion.

The wireless company received a letter[3] from the Navy Department to the effect that by order of the Administration the patents had been turned over to the Navy Department. A written request[4] was forwarded to the Administration, pointing out that the above-mentioned property had been confiscated by the Government without a hearing and asking for a hearing. No reply was received.

---

[1] Russel *vs*. United States, decided in 1900, 182 U. S. 516.

[2] Letter April 19, 1906.

[3] Letter No. 137,244, July 11, 1906.

[4] Letter April 3, 1907.

The above is given as an illustration of the effect of the present law under which an inventor has no legal remedy against the confiscation of his patents by the United States Government. Among other recent instances of confiscation of inventions by the Government may be mentioned those of the Krupp and Armstrong Companies, the San Francisco Dry Dock, etc.

As the situation is not generally understood attention is here called to it. It should be remedied, as it operates very injuriously as regards the Government departments themselves. The Government is deprived of the services of American inventors who either place their talent at the disposal of other countries, as in the case of Hiram Maxim, or turn their attention to other lines. The general result is that the United States Government, instead of leading other nations, is obliged to follow after and copy, though the success of the United States Navy in developing submarine boats is an illustration of what can be accomplished in cases where the inventor has been able to develop his work without confiscation.

In 1906 President Roosevelt's attention was called to the above facts. He was asked if the administration would not introduce a bill to remedy this state of affairs. He replied that the administration had too many bills of its own to look after, but, on further inquiry, stated that if such a bill was introduced the administration would not oppose it.

On the strength of this promise a bill was introduced and unanimously reported, as follows:

HOUSE OF REPRESENTATIVES, 60TH CONGRESS, 1ST SESSION, REPORT No. 184

The Committee on Patents, to whom was referred the bill (H. R. 7653) to amend section 4919 of the Revised Statutes of the United States, to provide additional protection for owners of patents of the United States, and for other purposes, have considered the same, and recommend that the bill do pass with the following amendment:

In line 7, page 1, strike out the words "has been or," and insert the word "hereafter" after the word "shall."

A bill substantially the same as that now reported was passed by the Senate at the last Congress, and favorably reported to the House, but at too late a day in the session to receive consideration.

The object of the bill is to provide for owners of United States patents a remedy for the taking of their property by the United States for public use, when such taking occurs without the license or authority of such owners and without compensation.

In England and in practically all over civilized countries, except Russia and the United States, the Government can not appropriate an invention without paying a fair price for it. A regular tribunal is charged with the duty of determining what is a fair price for the use of an invention appropriated by the Government in case the Government considers the inventor's charge to be excessive. The United States habitually appropriates at its pleasure the patented inventions of its citizens and declines payment therefor. And this notwithstanding the fact that according to the decisions of the Supreme Court a patent of the United States is property within the meaning of the term as used in the Constitution and laws of the United States, and the use of a patented invention by the Government is a taking of private property, which can not be done lawfully without compensation to the owners. (Solomons *v.* United States, 137 U. S., 342, 346; McKeever *v.* United States, 14 Ct. Cls., R., 396; Affirmed S. C. 18 Ct. Cls., R., 745.)

But notwithstanding this right to protection which patentees and other property owners derive from Article V of the Amendments to the Constitution, it has been held by the Supreme Court that the owner of a patent can not restrain its infringement by the United States or an officer or agent of the Government. (Schillinger *v.* United States, 155 U. S., 163 (1894); Russell *v.* United States, 182 U. S., 516 (1900).)

In both of these cases the court held that in the absence of an express contract between the Government and the patentee, or transactions between them from which a contract may be implied, no court of the United States is vested with jurisdiction to entertain a suit or action by a patentee seeking to recover compensation for the use of his invention by the Government.

How next to impossible it would be to make a case of implied contract which would render the Government liable under the court's decision may be inferred from the following statement of the facts appearing in the Russell case just cited. It there appeared that at the Government's invitation Russell exhibited his patented invention to a board of officers appointed by the Secretary of War. The Government announced that it would adopt and use a device embodying his invention. Prior to the adoption and use of the device Russell communicated his patent to the War Department, showing that his patent covered the device and tended the use of his invention to the Government for reasonable compensation. The Government proceeded to use the device without denying Russell's right to compensation, but with the remark that he should seek his remedy by some means other than Executive action. And the Russell case is only a sample case; one of many.

It seems to be necessary and proper to provide for patentees a remedy, such as the passage of this bill will secure, for the invasion of their rights. Without such remedy, patentees are the only persons who are outside the protection of Article V of the Amendments of the Constitution. "Nor shall private property be taken for public use without just compensation."

Without such remedy a patent is not what it purports to be on its face. Many inventors have spent years of their lives and practically bankrupted themselves in developing inventions primarily of use to the Government, only to find in the end, after their property has been seized by the Government, that they have no legal means of redress, and that the governmental Departments will not recognize the decisions of the courts.

Without such remedy there is a ridiculous discrimination between inventors. The inventor of a children's game or of a new brand of chewing gum is protected by the courts. But the inventor of a device which may save the nation from an humiliating defeat in time of war, or reduce the cost of carrying the mails, or reduce the number of shipwrecks on the coast, is afforded no protection; the governmental Departments have the power to confiscate his property and habitually exercise that power. It may be a new type of breech mechanism, or a dry dock, or a method of communicating with ships at sea; if the invention is valuable the Government can and does seize it, though the inventor may have spent years of his life and bankrupted himself and his friends in developing it.

It may be conceded that the Government ought to have the right to appropriate any invention necessary or convenient for natural defense or for beneficent public use, and that, too, without previous arrangement or negotiation with the owner. Nevertheless, the appropriation having been made it would seem that justice to the citizen demands that in due time he should receive fair compensation for his property.

The claim is made by some that the Government, being the grantor of the patent, ought to have the right to use without compensation such inventions as are necessary for its purposes.

One answer to this is that there is no such limitation or reservation in the law governing the granting of patents; and another answer is that if that were the law there would be no time, brains, or money spent by anyone in inventing those things for which there would be no remuneration.

But it is useless to multiply reasons to justify the passage of the bill. The one fundamental reason already assigned is unanswerable—that no American citizen's property can be appropriated for public use by the Government or by anyone else without compensation being made therefor.

The amendment proposed, by striking out the words " has been or " and the use of the word " hereafter," in line 7, page 1, is deemed advisable, that there may be no question arising upon statutory construction that the law is not retroactive in its effect, but will apply only to future appropriations of patents by the Government.

It passed the House of Representatives by a large majority, the leaders of both the Republican and Democratic parties speaking in favor of it. It passed in the Senate unanimously. It did not become a law, however, as President Roosevelt declined to sign it, though its signature was strongly recommended by Secretary Taft, Senator Knox, and others. No reason was given by President Roosevelt for declining to sign the bill, but it is understood that his action was due to the fact that the ratification of the proposed wireless treaty had been opposed by one of those interested in the passage of this bill.

Discussion on "Primary Standard of Light."

(Subject to final revision for the Transactions.)

A. E. Kennelly (by letter): The paper presents a certain fundamental physical proposition relating to a fundamental standard of luminous intensity, and also a practical proposal suggesting a means for carrying out the proposition. In so far as concerns the physical proposition, it seems to be unassailable, and to offer a theoretical solution for the problem of realizing a standard luminous intensity of definite physiological value, and definitely measured energy; that is, in ergs per steradian, or ergs per cubic centimeter from point to point of the luminous beam.

As regards the practical suggestion of carrying this method into effect, it seems to me a great deal of experimental work will be necessary to develop the method. It would be necessary not only to develop the bolometric method of measuring the energy in the three component beams with a satisfactory degree of accuracy for standard purposes, but it would also be necessary to determine the physiological stimulus of each of these three colors throughout the range of intensity required in photometric measurements. This is for the reason that in order to measure the light given by any particular lamp, such as a Hefner flame, for example, it would be necessary to arrive at a color balance on the photometer, by altering the ratio of the intensities in the three component beams. This would involve an alteration in the luminous stimulus, or light sensation, of unit intensity of the composite light so produced, and the luminous intensity of the Hefner flame could only be expressed in terms of standard light after taking into account the change in physiological effect of the altered components.

Nevertheless, Dr. Steinmetz's proposal is definite, and offers a definite chance of realizing a true determination of light in terms of energy, as the outcome of experimental research along three defined wave lengths or luminous frequencies.

The suggestion in the paper that the scale of abscissas should be logarithmic, instead of numerical, seems to be excellent for many graphical purposes. According to this suggestion, the visible spectrum would be divided into three larger regions (violet, green, and red) and four smaller regions, or "semi-tones," namely, indigo and blue, on one side of the green, and yellow and orange on the other. This would make an optical scale of approximately three tones and four semi-tones, or ten semi-tones altogether: The division of the spectrum would thus naturally fall into decimal subdivisions instead of into Angström units. Each first decimal place, or tenth root of 2, would correspond approximately to a semi-tone of color, while two such decimal divisions would correspond approximately to a tone of color.

Edwin P. Hyde (by letter): It would be very desirable indeed, both from theoretical and practical considerations, to be able to define our standard of light in terms of the C. G. S.

system of units, rather than have it without any known connection with other physical quantities. The suggestion of Dr. Steinmetz would seem to make possible such a definition. According to the suggestion we would define, not a standard of luminous intensity, but a standard of luminous flux; and we would measure the intensity of an unknown source by comparing the illumination produced by the flux from that source with the illumination produced by the standard flux. Since according to our present methods what we actually do is to compare illuminations and reason by means of known or assumed laws to the luminous intensities of the sources producing the illuminations, it is only necessary that we have a standard luminous flux, and not that we have a source of standard luminous intensity.

The principal difficulty to be overcome in realizing such a standard as Dr. Steinmetz suggests is in accomplishing with the requisite accuracy the absolute measurement of the small amount of energy contained in a single bright line in the visible spectrum. The determination of the proper proportions of energy in the three regions of the spectrum to give the required color, and the reproduction of these three colors in their proper proportions, could probably be accomplished with sufficient accuracy, but the determination of the energy of each region in absolute units would be a much more difficult undertaking. It would seem to me that a suggestive method of procedure might consist of: first, in obtaining as intense radiation as possible for the objective measurements, and then cutting down the intensity, if necessary, by sectored disks or other suitable means for the photometric measurements; and secondly, in measuring objectively the energy both of the component wave-lengths and of the combined flux—the former to give the proper proportions, and the latter to give the total luminous flux. By this method, slight errors in determining the proper proportions of the component parts would only enter as second order effects if the total flux is measured accurately; and the larger the total quantity of energy measured objectively the more accurately can the measurement be made when we are dealing with relatively small quantities of energy.

Although there would be numerous advantages in such a standard as Dr. Steinmetz proposes, if such a standard could be realized, there is one slight disadvantageous feature, which, however, is not serious. It has usually been customary to take the standard of white light as the standard also of spectral distribution in spectrophotometric measurements. This can only be done, of course, when the standard has either a continuous spectrum, or else a large number of bright lines well distributed in the visible region of the spectrum. The use for spectrophotometric measurements of such a standard as that proposed by Dr. Steinmetz would not seem feasible.

With the adoption of a common international unit of luminous intensity maintained arbitrarily by means of incandescent lamp secondary standards, such as has been proposed, the demand for a suitable primary standard of light is not as urgent as it has been heretofore; it is nevertheless just as important as ever, and the proposal of Dr. Steinmetz to define the standard in watts, with a prescribed spectral distribution, is very suggestive.

DISCUSSION ON "AN IMPERFECTION IN THE USUAL STATEMENT OF THE FUNDAMENTAL LAW OF ELECTROMAGNETIC INDUCTION"

(Subject to final revision for the Transactions)

Chas. P. Steinmetz (by letter): Mr. Hering's paper is interesting in that it draws attention to a looseness in the form of expressing this law, which is frequently the cause of serious misunderstanding, and the waste of much energy and time. For instance, in the attempts to invent a coil-wound unipolar machine much useless effort could have been avoided by a clearer distinction between the general law and the special case of its application to a continuous closed conductor. While Mr. Hering's experiment is interesting in showing an instance of a closed electric circuit in which the number of interlinkages with the lines of force changes without inducing an electromotive force, it is not startling to me, as the reverse case, the electromagnetic induction of an electromotive force, in a closed circuit, without any change of the number of interlinkages of the circuit with the magnetic flux, is illustrated by practically every unipolar machine. There are thousands of kilowatts of such machines now in commercial operation.

The general law of electromagnetic induction is:

> In a conductor moving relatively to a magnetic field, an electromotive force is induced which is proportional—and in absolute units equal—to the product of the intensity of the magnetic field, and the components of the length, and of the velocity of the conductor at right angles to the magnetic field and to each other.
>
> If an electric conductor moves relatively to a magnetic field, an electromotive force is induced in the conductor, which is proportional to the intensity of the magnetic field, to the length of the conductor, and to the speed of its motion perpendicular to the magnetic field and the direction of the conductor.

$$e = e\, v\, H \sin\alpha \sin\beta \sin\gamma \times 10^{-8} \text{ volts.}$$

Using the pictorial representation of the magnetic field by the lines of magnetic force, as given by Faraday, this means. that the electromotive force induced in the conductor equals the rate of cutting of the conductor through the lines of magnetic force, that is, gives: $e = \frac{d\,\phi}{d\,t} 10^{-8}$ volts, where $d\,\phi$ are the lines of force cut by the conductor during the time $d\,t$.

Applying this general induction law to the special case—which is the most important, but not the only case met in electrical engineering—of a continuous conductor closed upon itself, or a turn, it follows, as conclusion, that the total electromotive force or resultant electromotive force induced in the turn equals the rate of change of the total number of magnetic interlinkages of lines of magnetic force enclosed by the turn, hence is: $e = \frac{d\,\phi}{d\,t} 10^{-8}$, where ϕ is the number of lines of magnetic force enclosed by the turn or, leaving Faraday's pictorial representation, ϕ is the magnetic flux enclosed by the turn.

Maxwell and J. J. Thompson's statement, as quoted by Mr. Hering, are not the most general expressions of the law of induction, but its formulation for the special case discussed by these scientists, of a turn moving with regard to the magnetic field.

Mathematically speaking, we may see that Maxwell's law is the integral expression derived from the general or differential law by integration over the whole circuit, under the " terminal " or " limit " conditions of continuity of conductor and continuity of motion, and does not apply to Mr. Hering's experiment, or to the general design of unipolar machines, which do not fulfil the conditions of continuity of motion, but have parts of the conductor sliding over other parts.

Faraday's expression, of cutting of lines of magnetic force by the conductor, is the general law; but in its application to unusual cases it must be kept in mind that the " line of magnetic force " is merely a pictorial representation of the magnetic field in space, as characterized by the two constants, intensity, and direction. This pictorial representation, when carried so far as to apply to its physical existence, may lead to wrong conclusions; for instance, when discussing whether the lines of magnetic force of a revolving magnet move with the magnet or stand still. Assuming, for instance, a bar magnet of circular section $x^2+y^2=r^2$, revolving around its axis z. Then in any point in space, outside of the magnet as well as inside, the intensity as well as the direction of the magnetic field is constant; that is, the magnetic field is constant, or stationary in space, regardless of whether the magnet stands still or revolves. Assuming a second system of coördinates with the same axis, z, as the magnet, and with the other two axes, x_1, and y_1, stationary with regard to the magnet, and revolving in space with the revolutions of the magnet, then with this coordinate system, x_1, y_1, z, the magnetic field at any point, inside of the magnet as well as outside, is also constant in intensity and in direction; that is, is stationary. Or in other words, while the two coördinate systems x, y, z, and x_1, y_1, z_1, revolve with regard to each other, the magnetic field of the magnet is constant in intensity and in direction, that is, it is stationary, with regard to either. Physically, this is nothing exceptional; it merely means that the condition of stress, which we call magnetic field, is unvarying in its distribution in space as well as with regard to the revolving magnet. Picturing to ourselves the magnetic field as lines of magnetic force, it would mean that the lines of force are at the same time stationary in space and also revolving with the magnet. This suggests that all pictorial representations, no matter how useful, may occasionally become ambiguous. In such cases the only safe way is to go back to the entities proper, in the present case, the magnetic field as a quantity characterized by intensity and direction.

Unfortunately, in teaching, instead of the general law of induction, there is frequently given to the student, its specific application to the turn or closed continuous conductor as more convenient to illustrate and to understand. While in the introduction to the elements to electrical engineering this is permissible, to get a complete understanding of the phenomena of induction, it must be supplemented by an exact discussion of the general induction law, that is, the mathematical formulation of Faraday's pictorial representation.

A. E. Kennelly (by letter): The experiment described in the paper is both interesting and instructive. Although the experiment illustrates the proper application of the law of induction when applied to electric circuits, it does not in my opinion controvert the existing law when properly interpreted; that is, when interpreted as intended to be expressed by its founders, Faraday, Maxwell, and others.

When it is stated that the electromotive force round a circuit is equal to the time-rate of change of the flux linked with that circuit, it is inherently assumed that the circuit is not interrupted and then established around a new boundary. It means, as I understand it, that the circuit contains a simply connected region of magnetic flux, through which the boundaries may be flexibly caused to wander at will. Maxwell specifically rules out the case of multiple-connected regions, by a special proposition to that effect. In Mr. Hering's experiment, the boundary of the circuit is cut at one point, and simultaneously a second circuit embracing flux is introduced at the gap, in such a manner that by sliding along the boundaries of the second circuit, the magnetic flux may be caused to disappear from the embrace of the first circuit without any intersection of flux by the edge of that circuit. This, to my mind, is juggling with terms, just as though the circuit were cut and then reclosed through a quiescent loop linked with a magnet. Manifestly, no current would be induced through the galvanometer by reason of that change, although in one sense of the word "circuit", all of the flux in the loop has suddenly been introduced into the circuit.

The instructive value of the experiment described in the paper lies, to my mind, in clearing up the question as to which is the primordial proposition; that electromotive force is induced (1) by the movement of magnetic flux across the boundary, or (2) by the introduction of flux into a loop or circuit. As ordinarily stated, the two propositions are as closely connected as the propositions concerning the priority of the chicken and the egg, because flux cannot cut the boundary of a loop at any point without altering the flux contents of the loop, nor can the flux in a loop alter without cutting the boundary somewhere. The experiment shows, however, that where flux comes into a field from a balloon, as distinct from walking over a fence, no electromotive force is induced, and this indicates that the cutting is the primordial conception, to which enclosing is secondary. Of course this cutting electromotive force occurs as much in insulators as conductors, but can ordinarily be revealed only through the use of conductors. When, therefore, a closed circular solenoid, or anchor-ring, is wound with a primary and with a secondary coil, we know that in the steady state, if the solenoid is properly wound, there will be no external magnetic flux due to current in either winding; but the change of internal flux due to change of current in one winding induces electromotive force in the other, as in the ordinary transformer. At first sight, this would look as though there were change of enclosing flux without any cutting, but in the light of this experiment it seems clear that this is not the case. There must be cutting of flux passing from outside to inside of the secondary coil, but, incidentally, all the external flux cancels off, or becomes zero in the final steady state.

Summing up, then, I should think that this experiment shows that when the ordinary proposition is enunciated concerning induction of electromotive force with change of flux enclosed in a circuit, it should be borne in mind that the circuit is not to be juggled with by interrupting it and changing it from a simply-connected to a multiple-connected space. It must consist of a single, continuous boundary which, if it moves, moves continuously through simply connected space. In this understanding, I think we shall all agree.

Elihu Thomson (by letter): I agree with Dr. Kennelly in his view of the state of the case. By passing the spring clip over the magnet leg the circuit is virtually opened so far as magnetic induction is concerned, and an immovable section of conductor is substituted in the gap where all the flux to be cut then exists. The conclusion that the real physical substance of the circuit (the matter of the circuit) must cut or be cut by the lines is in accordance with my view of the subject. There are innumerable phenomena which have confirmed that idea of what is really the circuit to be considered. Otherwise in fact, the circuit is more metaphysical than physical, a sort of mental image only. I am glad Mr. Hering has tried the experiment, as it will tend to clear up matters which have troubled students in unipolar induction. I have long regarded Faraday's view of *line cutting* as much preferable and more universal than the theory of linkages simply.

The unipolar dynamo is quite practicable for large units of 220 to 550 volts or more, understanding that greater collector losses offset the commutation difficulties with ordinary types and that magnetic losses will probably exceed the calculated losses considerably.

There seems to be one universal law which might be expressed as follows: "It is not possible without chemical or thermoelectric action to generate a continuous current in a closed circuit without sliding contacts," or "A magnetic induction machine for direct currents must have a commutator or sliding contacts of some sort."

The experiment might be modified by boring holes through the magnet and inserting copper pins, the ends of which would be traversed by the ends of the spring clip. Manifestly since there would be no movement of these pins, there could be no electromotive force generated when they were traversed.

In a magnetic blowout arrester the static stress is exerted at full intensity across the narrower part of the gap in spite of the powerful field surrounding it. As soon, however, as the first slight spark jumps the gap (at the narrower part of course) the gases traversed by the current are deflected. Not, however, until the matter carrying the current has actually bridged the gap does the deflecting action of the field begin.

If the current be assumed to be a flow of electrons (negative) from one molecule to the next contiguous and so on, it is easy to understand why the *matter* of the circuit is the thing concerned and not merely an assumed line or direction.

It may be proper to regard the experiment as involving a form of unipolar induction, inasmuch as it is not possible to use a coil of numerous turns but one of a single turn. If the coil were to be used, it would have to be made up of loops which could open and pass over the magnet by riding upon a series of pins, insulated from each other, projecting through the magnet section, as suggested by me in a modification. Some twenty-five or thirty years ago I leaned to the more generalized view of Maxwell's law referred to in the paper, but gradually grew out of it and adopted Faraday's view of line cutting as the essential thing. The lines must be cut by the moving conductor, or the lines must move and cut the conductor in order to generate an electromotive force, and the potential difference arises in only that section of the conductor which cuts or is cut by the lines.

I think I should have to modify the universal law, which I proposed above, a little in view of Dr. Bruger's direct-current machine. Inasmuch as the resistance of a coil of bismuth wire may be changed by a magnetic field, it is evident that if the magnetism is so used as to increase the resistance of the bismuth when a current in one direction would be induced in it or a part of the circuit in series with it, and if, when the opposite pulse was induced, the resistance of the bismuth were lower, this would amount to a partial commutation but would be accomplished without slipping contacts or any ordinary form of commutator. The result, however, would seem to be more of a pulsating current or a current in which the values of the half waves were unequal, or the wave unsymmetrical with respect to the zero line; a partially rectified current, so to speak. The mercury arc rectifier accomplishes the production of an alternating current from a direct current, and other instances exist, as is well known, of partial rectification by electrolytic cells, vacuum tubes, and the like. It is conceivable that it might be possible to use even a selenium cell in place of the bismuth of Dr. Bruger, putting the selenium in the light at one time and in the dark at another, to affect synchronous alternating pulses differently and give a balance of direct current. A partially rectified current can be sifted so that the direct-current component goes one way, and the alternating-current component another way, as by connecting the terminals by a non-inductive resistance and connecting the direct-current receiving apparatus from the same terminals through a high inductance.

In my paper many years ago, on " Magnetism in its Relation to Induced Electromotive Force and Current " read before the American Institute of Electrical Engineers, I rather emphasized the view that a line of force can only finish by collapsing to a point or infinitesimal closed chain, and can never be broken or opened. By this view, to my mind, we have the only possible explanation for the varied phenomena of induction; that is, we have the only possibility of getting any good physical conception of what takes place.

W. S. Franklin (by letter): What is said in this paper concerning the law of induced electromotive force is, I think, entirely correct. I must say, however, that I have never looked upon Maxwell's statement of this law in a way which would lead me to think of it as not strictly correct. It has always seemed to me that the differential equations of the electromagnetic field in *stationary* and in *moving* media cover the ground completely without any possibility of a misunderstanding.

The point of view of looking upon the circuit as abstracted from definite identifiable material may be illustrated in its extreme form as follows: imagine a sheet of copper placed at right angles to a steady magnetic field; imagine an electric circuit in the form of a circle which starts at a point on the copper sheet and spreads outward like a circular ripple on the surface of a pond. This moving circuit, according to Mr. Hering's interpretation of Maxwell's generalization of Faraday's law, should have electromotive force induced in it, and therefore the stationary sheet of copper in a steady magnetic field should have eddy currents circulating in it. Of course I understand it is precisely this absurd conclusion that is being objected to. My point is this: I do not believe that those who accept Maxwell's generalization have forgotten the idea of *actual cutting of lines of force* by the material of the electric circuit; but it may be said they are likely to be led to forget it because of the form of Maxwell's statement of the generalized Faraday law. Perhaps that is true, and yet the difficulty reduced to its simplest terms is the difficulty of partial differentiation; a physical condition is a function of several independent variables, such, for example, as space and time. One is *obliged* to think of one variable only changing at a time, but one should never for this reason surrender the *knowledge* that all things change together.

Percy H. Thomas (by letter): If I understand this paper correctly, the experiment is not conclusive, and for the following reasons: in drawing off the loop, as long as the ends are rubbing on the sides of the magnet, the lines of force may be said to be still within the loop. When next those ends come in contact, preliminary to their separation from the magnet, the galvanometer becomes short-circuited and protected from any influence of a later change of lines in the loop. In other words, the original loop becomes two loops by being connected across the middle. None of the lines of force is evidently in the lower loop; all are in the upper loop. The upper loop is then *broken* by withdrawing the wires entirely from the magnet, which of course will give no deflection. What has really been done, if I understand the experiment, is that a portion of the original loop containing the galvanometer (but none of the lines) has been *cut off* by short-circuiting, from the whole loop while it still contains the lines, and then the main loop has been opened.

W. P. Graham (by letter): It is perhaps open to question whether the statements of the law of electromagnetic induction by Maxwell and by J. J. Thomson, as quoted by Mr. Hering, are sufficiently precise. Their lack of precision may be simply illustrated as follows: let a wire be bent round the pole of a magnet so as to form a closed circuit linking the magnetic flux. Now let the ends of the wire be separated and the magnet slipped out between the ends so that the flux ceases to link with the wire. Finally, let the wire be again formed into a closed circuit with which the flux does not link. If this re-established circuit be regarded as the original circuit, the flux through the circuit has certainly changed without inducing any electromotive force in the wire.

I think most of us would regard such an interpretation of Maxwell or Thomson as a quibble. But essentially the same interpretation is made by Mr. Hering in discussing the experiment with the galvanometer and copper strips. As soon as the copper strips strike the iron, the original circuit, made up of copper strips and galvanometer is opened, but a new circuit including copper strips, magnet iron and galvanometer is established. And as long as the copper strips make contact with the magnet, there is no change of flux through this new circuit. When the strips leave the magnet, this new circuit is broken, and the old circuit from which the flux has been removed after opening it, is re-established. A more accurate statement would perhaps be that as soon as the strips strike the iron, the old circuit is opened and a new circuit established, to be followed by an infinite succession of other new circuits as the strips slip over the iron, and that the flux is removed from each one of this succession of circuits, by opening each in turn, and establishing its successors; but that there is no change of flux through any individual circuit of the series so long as that circuit is closed.

I agree entirely with Mr. Hering that in presenting the law of induction to a class of students, the cutting of the flux by the conductor is the point to be emphasized and that Faraday's statement of the law is to be preferred.

George T. Hanchett (by letter): It would appear from this that some modification of Maxwell's version of the laws of induction should be made. Let us consider two other methods of trying this experiment. The first of these is illustrated in Fig. 1. The test circuit is slipped over the magnet in the usual manner and the initial deflection is observed. It is then unlinked (?) with the magnetic circuit by the following device: The wires are short-circuited at *A* and the clips at *B* drawn over the magnet limb and removed. There will be absolutely no deflection at the galvanometer as a result of this action, provided, of course, that the short-circuiting is perfect.

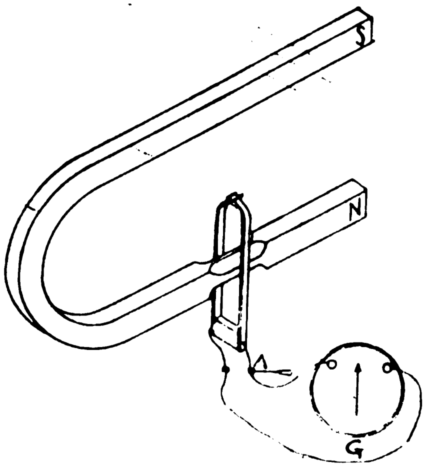


FIG. 1

The second experiment, illustrated in Fig. 2, provides two clips similar to those mentioned by Mr. Hering, but instead of drawing them over the body of the magnet, they are drawn over a tube or annulus surrounding the limb of the magnet and insulated therefrom. It is observed that the detector circuit is first short-circuited outside the flux field before any attempt is made to unlink it, and by this means the circuit is divided into two portions, one containing the galvanometer or detector, which is short-circuited and removed, and the other containing the flux, which is short-circuited and not removed from the magnetic circuit at all. No lines of force are cut by or varied in number within a circuit, and in strict accordance with Maxwell and Faraday no deflection results. In Fig. 2 I have left the loop or ring surrounding the magnet limb in order to point out clearly what Mr. Hering has evidently failed to see—that in performing his experiment he has left an exactly similar flux containing a portion of the circuit behind him in the form of a loop of steel which is a part of the magnet limb itself.

There is no unlinking of the magnetic and electric circuits, but instead a mechanical unlinking which deceives the eye. Electrically, the circuit is linked with the magnet, then a new portion of circuit is added in the form of the magnet limb itself which is ingeniously caused to do all the linking. Next the original circuit now free from flux is removed. This is the exact analogue of the experiment which is the subject of this discussion.

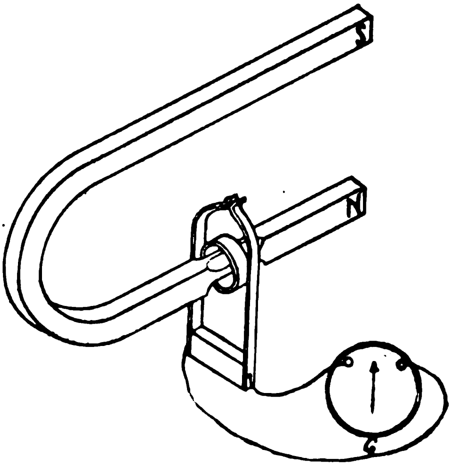


FIG. 2

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

REPORT OF THE BOARD OF DIRECTORS FOR THE FISCAL YEAR ENDING APRIL 30, 1908.

The Board of Directors presents herewith for the information of the Institute a report of its work during the year, and of the various standing and special committees, also the financial standing of the organization.

The Annual Convention was held at Niagara Falls, June 25-28, 1907. The total registered attendance was 459. Thirty-two professional papers, including the President's annual address, the report of the Committee on a Code of Ethics, and the revised Standardization Rules, were presented and discussed.

The Board of Directors has held 11 regular monthly meetings and one special meeting during the year, and the Executive Committee one meeting.

Upon recommendation of the Finance Committee, and with the approval of the General Counsel, *advance* payments were made upon the Institute's share of the land occupied by the Engineers' building. The total amount paid was $81,000, covering nine out of the twenty annual instalments, up to and including July 1, 1916. These payments were made from the Land, Building and Endowment Fund.

Upon recommendation of the Finance Committee the Institute has purchased for investment $12,000.00, face value, New York City registered bonds drawing interest at 4½ per cent., which were paid for out of the current bank balance.

Board of Examiners.—Eleven meetings were held during the year, at which applications for election as Associates, enrolment as Students, and transfer to the grade of Member, have been reported to the Board of Directors as follows:

Recommended for election as Associates	1,588
Not recommended for election as Associates	8
Recommended for enrolment as Students	687
Recommended for transfer to the grade of Member	53
Not recommended for transfer to the grade of Member	23
Held for further information	8
Total number of applications considered	2,367

Sections Committee.—Prior to the adoption of the new Constitution a year ago the local organizations were divided into three classes: namely, Branches, University Branches, and Student Meetings. The total number of local organizations of all classes on April 30, 1907, was 33. Under the new Constitution the local organizations were divided into two classes: Sections and Branches. There are now 48 local organizations, 22 of which are Sections, and 26 Branches; an increase of 15 during the year. Of this number four are Sections, organized at Toledo, Cleveland, Norfolk, and the City of Mexico. The other 11 are Branches located in various parts of the country. In addition to the Sections and Branches organized during the year, the committee has received many inquiries from different cities respecting the organization of Sections. The reports of local secretaries show that 284 meetings were held at the different Sections and Branches during the year, with a total attendance of 11,604. At these meetings 204 original papers were presented, in addition to which 104 Institute papers were discussed. The increasing interest taken in section work as shown by the facts presented in this report is further indicated by the large number of visiting speakers who have at various times during the year been invited to take part in section and branch meetings. The results of the year's work are very encouraging, and there is every reason to believe there would be even a more satisfactory showing had all the local meetings been reported to the secretary of the Institute.

Building Fund Committee.—Notwithstanding the financial depression of the latter half of the year, the Building Fund Committee is able to report that the number of subscribers to the Fund has increased from 934 to 1,538. The amount subscribed during the year was $6,464.68, showing an average for the new subscribers of a little over $10.00 per capita. The amount collected and placed in the treasury of the Institute during the year by the committee was $10,780.23. The total amount now pledged by the efforts of the committee is $170,199.15, out of which $135,609.50 has already been collected. It will thus be seen that the Fund has made substantial and encouraging progress, and it is hoped that with the return of prosperity the remaining $15,000 required may be obtainable from the membership, so that the Institute may enter upon its second quarter of a century in 1909 absolutely free of debt. While the number of subscribers is already so large, it is believed that amongst those who have not yet subscribed, and especially amongst the newer members, there will be found enough public spirited men to extinguish the small amount of indebtedness not now provided for. The committee feels strongly the desirability of basing the subscription list as broadly as possible, and while it has been successful in securing some very large individual gifts, it has and is still directing its efforts more particularly in the line of smaller amounts.

Standards Committee.—The Standards Committe has held three meetings since its appointment. Through its members it has engaged in a number of conferences with representatives from other national associations, including the National Bureau of Standards, with a view to assisting in a movement for an international agreement as to standard of light. The work of recomputing a wire table is held in abeyance until the National Bureau of Standards announces the value of the temperature coefficient of resistivity of copper, which is being determined.

Library Committee.—The complete report of this Committee will be printed in the Institute PROCEEDINGS in the near future.

Committee on Bibliography.—The catalogue of the Latimer Clark

Library, which was presented to the Institute in 1901 by Dr. Schuyler Skaats Wheeler, is now ready for printing. A very large amount of painstaking effort has been expended upon this work, and the proofs have been carefully revised by many authorities both in this country and abroad.

Meetings and Papers Committee.—During the year this committee has arranged for eight regular and two special meetings and a meeting in honor of Lord Kelvin. The special meetings were on the subject of Forest Preservation and Technical Education, the latter under the auspices of the Educational Sub-Committee. A total of seventeen papers were read at these meetings.

The regular annual convention was held at Niagara Falls under the auspices of the last committee. Preparations are now being made for the coming convention at Atlantic City. About thirty-three papers, of which many are short, will be presented.

The committee has made a vigorous effort to publish the papers in the issue of the PROCEEDINGS immediately in advance of the meeting, and this result has been accomplished in all instances with one possible exception. It is believed that it is a great advantage for the membership at large to have the papers in their hands some days in advance of the meeting. The manuscripts for the convention papers have nearly all been received and will be published in the May and June PROCEEDINGS as far as possible.

It has been the practice of the committee during the present year to consider the various sub-committees as practically independent bodies, except so far as the arrangement of dates and the editorial revision of papers is concerned. The initiative in the choice of subjects, the soliciting and accepting of papers, etc., have been in the hands of sub-committees. This is believed to be the only practical method of conducting the work. The present arrangement of the sub-committees, if treated in a liberal spirit, seems to be a very desirable one.

Papers presented at the Section meetings have been considered by the same standard as the papers submitted for the New York meetings, and a number have been printed in the PROCEEDINGS during the year.

Educational Sub-Committee.—During the winter several meetings of this committee have been held in New York City. As a sub-committee of the Meetings and Papers Committee, the first function of this committee is to obtain papers on the subject of technical education, and to arrange for meetings. Accordingly a special meeting of the Institute was held on January 24, 1908, at which two papers on engineering education were presented. Eighteen members of the Institute took part in the discussion which followed.

The University Branches throughout the country were urged to take up the subject of technical education and devote a session to it, which many of them did. The chairman of this committee conducted the meeting on this subject at the University of Illinois. He also visited several other technical institutions during the year. The committee has arranged for the presentation of several papers on technical education at the coming convention at Atlantic City.

Railway Sub-Committee.—The Railway Committee during the past year has acted in conjunction with the Meetings and Papers Committee in obtaining papers and speakers on railway subjects. The committee suggests that one of its members be appointed on the Standards Committee, and that all matters relating to the standardization of railway apparatus or railway practices be referred to it by the Standards Committee. The field of usefulness of the Railway Committee appears to be threefold—acting in an advisory capacity to the Meetings and Papers Committee the Standards Committee, and the High Tension Transmission Committee, and while its activities have been largely limited to acting in conjunction with the Meetings and Papers Committee during the past year, it is probable that the continued existence of the committee will demonstrate the benefit resulting from broadening its duties.

Editing Committee.—Since September, 1907, there have been edited and published eight numbers of the PROCEEDINGS. The total number of pages of these PROCEEDINGS is 1494; of this total, 454 pages have appeared as Section I, 1040 pages as Section II. Of the 1040 pages in Section II, 580 pages were devoted to technical papers, and 460 pages to discussions. In editing the discussions, the Committee has endeavored consistently to make them approach the well established Institute standards of style as to substance and form.

This committee has conferred with the Meetings and Papers Committee in regard to the publication of Volume XXVI of the TRANSACTIONS. This conference has decided that the TRANSACTIONS for 1907, consisting of approximately 1850 pages of papers, discussions and reports, be printed in two parts. Part I is now at the bindery and Part II is in press. Both parts will probably be ready for distribution in July.

Law Committee.—The Law Committee held six meetings during the year. Its most important work has been the revision of the By-laws to conform to the new Constitution. In this work the committee was assisted by members of other committees and by suggestions and comments from Institute members. The proposed new By-laws are now in form for presentation to the Board of Directors.

Other matters to receive the attention of the committee during the year were: the discrepancy between the dates of the Annual Meeting as set forth in the Charter and in the Constitution; the resolutions of the past-presidents embodying several important suggestions; resolutions of the Toronto Section respecting an intermediate grade of membership in the Institute.

Code Committee.—The Code Committee has held five meetings during the year for the discussion of some of the more important changes which have been proposed for embodiment in the National Electrical Code. The committee requests that any member of the Institute who may have noted instances of ambiguity in the present rules of the code bring the matter to the attention of Mr. C. M. Goddard, Secretary of the Underwriters Electrical Committee, 55 Kilby Street, Boston, Mass., preferably with a suggested modified wording to avoid the ambiguity.

The Code Committee was officially represented by its chairman at the meeting of the Underwriters National Electric Association, March 25 and 26; also of the meeting of the National Conference on Standard Electrical Rules on March 27.

Committee on Forest Preservation.—This committee has devoted its efforts largely to emphasizing the importance of forest preservation from the standpoint of the protection of water powers. As a result of the suggestions of the committee, meetings devoted to this subject were arranged by the local officers of the Atlanta, Boston, Minneapolis, Pittsfield, and Urbana Sections. Through the coöperation of the Meetings and Papers Committee Mr. Gifford Pinchot read a paper on the " Conservation of Natural Resources" at a special New York meeting of the Institute.

Through the courtesy of the Forest Service copies of the report of the Secretary of Agriculture on Southern Appalachian and White Mountain Watersheds were sent to all members of the Institute.

In accordance with its instructions the committee transmitted to the members of congress the resolutions on forest preservation adopted by the Board of Directors, and the Institute was represented at the congressional hearing on the Appalachian Forest Bill by Messrs. Schoen and Waddell, who have already presented their report. That many members of congress do not appreciate the importance of the protection of water powers has been conclusively demonstrated during the present session, and this committee feels that the Institute as an organization as well as the individual members should exert all legitimate influence to further legislation tending to protect the head-waters of streams on which important water powers are located. It is only by the active efforts of every one interested that any results can be accomplished.

International Electrotechnical Commission.—No meeting either of the International Electrotechnical Commission or of the United States subcommittee has been held during the year. A meeting of the International Electrotechnical Commission is contemplated for next fall, in London.

Various communications have been received from the acting secretary of the International Commission, and replies have been forwarded. In particular, a glossary of terms, A-G, prepared by the British special committee on nomenclature, was received in February, for consideration. It was transmitted to the Standards Committee, and received the consideration of that committee in March. The opinion and suggestions of the Standards Committee were communicated to the acting secretary of the Commission in London, under date of March 19, 1908.

Code of Ethics Committee.—A reprint of the proposed Code was mailed to all members in September, 1907, with a request for suggestions and criticisms, and a large number of very interesting and valuable replies were received.

Two meetings of the committee have been held at which the subject was discussed, but definite action was not taken, as all the members were not present.

Upon invitation of the Faculty of Science of Columbia University, the chairman made an address upon the subject before the graduating class.

Edison Medal Committee.—Competition for the Edison Medal under the terms of the original " Deed of Gift Creating the Edison Medal " having been demonstrated a practical failure, a new and substitute deed of gift has been executed.

By the terms of the new deed, the Edison Medal is no longer open to competition, but is to be awarded for " Meritorious Achievement in Electrical Science, or Electrical Engineering, or the Electrical Arts."

The next important work before the committee is to formulate new By-laws to govern its proceedings in consonance with the new deed.

Increase of Membership Committee.—This committee has been continuously active in bringing the advantages of Institute membership to the attention of desirable candidates. The number of applications for admission to the Institute as Associates received from October 1, 1907, at which time the present committee began its work, to April 30, 1908, is 874. No doubt a considerable number in addition will be received during the next few months, as a result of letters and printed matter already forwarded to prospective applicants whose names have been suggested to the committee.

Membership.—The present total membership and the increase during the past year are indicated below:

	Hon. Mem.	Mem.	Asso.	Total
Membership April 30, 1907	2	536	3,983	4,521
Additions:				
New associates	...	...	1,361	....
Transferred	...	43	....	....
Deductions:				
Died	1	1	21	....
Resigned	...	3	54	....
Dropped	...	2	126	....
Transferred	...	...	43	....
Membership April 30, 1908	1	573	5,100	5,674

Net increase in membership during the year 1,153

Resignations.—The following Members and Associates have resigned during the year in good standing:

Members.—C. Batchelor, D. H. Fitch, George A. Redman.

Associates.—P. L. Anderson, C. A. Babtiste, C. D. Bailey, T. P. Bailey, F. P. Beach, T. W. Blake, J. H. Brown, J. S. Butler, P. G. Chace, E. H. Clarke, F. E. d'Humy, R. N. Dickinson, T. E. Doubt, G. F. Durant, J. M. Eglin, A. S. Fairbanks, T. Z. Franklin, C. Furgueson, W. H. Gallaher, L. T. Girdler, Louis Glass, H. C. Goldrick, Heatley Green, E. C. Hall, L. I. Hall, N. H. Heft, C. M. Heminway, Ho Hidetaro, J. S. Hill, Robert Hiltbrand, E. Hockett, A. C. King, A. H. Lidderdale, A. Marston, H. H. B. Meyer, S. A. Moss, L. C. F. Nautre, J. S. Neave, E. J. O'Beirne, A. G. Palgrave, C. C. Parks, H. A. Pharo, A. Pratt, L. W. Pratt, W. T. Ritchie, Bernard Rowntree, A. Hugh Scott, Oliver Shiras, J. F. Skirrow, B. K. Sweeney, H. P. Tewksbury, J. C. Walter, A. J. Wood, F. V. Young.

Total resignations, 57.

Deaths.—The following deaths have occurred during the year:

Honorary Members.—Lord Kelvin.

Members.—C. K. Stearns.

Associates.—F. C. Barr, U. S. Bell, T. V. Bolan, E. B. Brisley, E. Danielson, L. J. Deremo, C. D. Howell, W. A. Kreidler, L. J. Magee, C. P. Matthews, L. K. Perot, W. J. Phelps, H. L. Price, O. R. Roberson, Paul Robinson, J. M. Simpson, J. J. Skidmore, L. W. Snowden, F. P. Spiese, D. B. Watson, Charles Williams, Jr.

Total deaths, 23.

Delinquent.—Dropped as delinquent during the year, 128.

The average receipts and disbursements *per capita* for the past seven years, are shown in the following table:

RECEIPTS AND DISBURSEMENTS PER YEAR PER MEMBER.

During each fiscal year for the past seven years.

Year	**1902**	**1903**	**1904**	**1905**	**1906**	**1907**	**1908**
Membership, April 30th, each year	1549	2230	3027	3460	3870	4521	5674
RECEIPTS PER MEMBER:							
Entrance Fees	$1.16	$1.59	$1.65	$0.83	$0.75	$0.90	$1.21
Dues	10.06	9.01	9.33	9.30	9.47	8.95	9.36
Transactions, Sales, Advertising	1.54	1.79	2.11	1.70	2.15	1.81	1.83
Badges	.26	.35	.39	.28	.27	.30	.43
Interest	.24	.21	.18	.21	.13	.25	.18
	$13.26	$12.95	$13.66	$12.32	$12.77	$12.21	$13.01
DISBURSEMENTS PER MEMBER:							
Transactions	$3.50	$4.67	$3.43	$3.77	$3.33	$2.83	$3.51
Salaries	2.78	2.49	2.50	2.20	2.64	2.53	2.55
Meeting Expenses, incl. Sections	1.13	.87	1.16	.82	.68	.68	.91
Housing	.94	.65	.79	.75	.68	1.33	1.15
Library, incl. Salaries	1.85	1.38	1.39	.81	.69	1.37	.51
Postage	.51	.69	.66	.66	.58	.59	.65
Stationery and Miscel. Printing	.53	.96	1.01	.70	.78	.85	.80
General Expenses	.59	.52	.45	.54	.29	.43	.62
Badges	.19	.27	.35	.25	.22	.29	.40
Express	.15	.15	.28	.22	.23	.28	.14
Advertising					.36	.30	.35
Office Fittings						.14	.14
Total	$12.17	$12.65	$12.02	$10.72	$10.48	$11.62	$11.73
Credit Balance per Member	$1.09	$0.30	$1.64	$1.60	$2.29	$0.59	$1.28

LAND, BUILDING AND ENDOWMENT FUND.

Receipts.		Disbursements.	
Before appointment of Committee	$ 6,100.00	Paid United Engineering Society, acct. of contract	$ 8,000.00
Collected by Committee	135,609.50	Paid United Engineering Society, acct. of mortgage	99,000.00
Interest on balances	4,998.40	Paid United Engineering Society, acct. of interest	16,289.45
		Expenses of Committee	10,070.14
		Balance in bank, May 1, 1908	13,348.31
Total	$146,707.90	Total	$146,707.90

General Financial Statement.

New York, May 13, 1908.

Mr. H. G. Stott,
President American Institute of Electrical Engineers,
No. 33 West 39th Street, New York City.

Dear Sir: The Finance Committee has during the past year conformed to the provisions of the Constitution and By-laws describing the duties of the committee. It respectfully submits herewith the report of the chartered accountants, Messrs. Peirce, Gimson & Company, who have audited the books of the Institute for the year.

The committee has personally examined the securities held by the Institute, and found them to be as stated in the balance sheet.

In accordance with instructions from the Board, your committee has invested a part of the Institute's surplus funds in high-grade securities and in view of the prosperous condition of the Institute, believes that additional security and increased income can be had by continuing to follow this policy of investing surplus funds not required for immediate use, in high-grade bonds.

Respectfully submitted,

CALVERT TOWNLEY,
Chairman Finance Committee.

New York, May 14, 1908.

MR. CALVERT TOWNLEY,
Chairman Committee on Finance.

Sir: In accordance with your instructions, we have audited the books and accounts of the American Institute of Electrical Engineers for the year ended April 30, 1908.

The results of this examination are presented in four exhibits, attached hereto, as follows:

Exhibit A. Balance sheet, April 30, 1908.

Exhibit B. Receipts and disbursements for general purposes for year ended April 30, 1908.

Exhibit C. Receipts and donations for designated purposes, also expenditures on same for year ended April 30, 1908.

Exhibit D. Condensed cash statement.

We beg to present attached hereto our certificate to the aforesaid exhibits,

Yours very truly,

PEIRCE, GIMSON & CO.,
Certified Public Accountants.

New York, May 14, 1908.

MR. CALVERT TOWNLEY,
Chairman Committee on Finance.

Dear Sir: Having audited the books and accounts of the American Institute of Electrical Engineers for the year ended April 30, 1908, we hereby certify that the accompanying Balance Sheet is a true exhibit of its financial condition as of April 30, 1908, and that the accompanying statements of Cash Receipts and Disbursements are correct.

PEIRCE, GIMSON & CO.,
Certified Public Accountants.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

BALANCE SHEET APRIL 30, 1908.

EXHIBIT A.

ASSETS.		
CASH:		
Land, Building and Endowment fund	$13,348.31	
Carnegie (Library) fund	3,168.19	
General Library fund	244.15	
Compounded Membership fund	5,600.00	
*Mailloux fund	1,017.35	
International Electrical Congress of St. Louis, 1904, Library fund	2,253.34	$25,631.34
†General cash in bank	12,225.71	
Secretary's petty cash on hand	500.00	12,725.71
United States Government Bonds 3s, 1918	8,000.00	
Premium on Bonds.	320.00	8,320.00
New York City 4½% Gold Bonds, 1957	12,000.00	
Premium on Bonds.	677.50	12,677.50
Equity in Societies Building (25 to 33 West 39th Street)	353,346.61	
One-third cost of land (25 to 33 West 39th Street)	180,000.00	533,346.61
Library volumes and fixtures	25,375.88	
Transactions	4,654.75	
Office furniture and fixtures	5,215.04	
Works of art, paintings, etc.	2,300.00	
Badges	576.35	38,122.02
ACCOUNTS RECEIVABLE:		
Members for past dues	11,365.75	
Members for entrance fees	425.00	11,790.75
Miscellaneous	280.54	
Subscriptions	26.98	
For advertising	2,007.25	2,323.77
Total Assets		$644,937.70

LIABILITIES AND SURPLUS.		
FUNDS:		
Land, Building and Endowment Fund	$13,348.31	
Carnegie (Library) Fund	3,168.19	
General Library Fund	244.15	
Compounded Membership Fund	5,600.00	
Mailloux Fund	1,017.35	
International Electrical Congress of St. Louis, 1904, Library Fund:		
Principal	2,146.12	
Unexpended Income	107.22	$25,631.34
Reserve fund (U. S. Govt. Bonds)		8,320.00
United Engineering Society (for cost of land)		81,000.00
Total liabilities		$114,951.34
SURPLUS:		
In cash	$12,243.06	
New York City bonds	12,677.50	
In property and accounts receivable	505,065.80	529,986.36
Total liabilities and surplus		$644,937.70

---

* The Farmers' Loan and Trust Co. deposit account includes $17.35 of the Mailloux Fund.

† $75.00 of the Weaver donation.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

RECEIPTS AND DISBURSEMENTS FOR GENERAL PURPOSES FOR YEAR ENDED APRIL 30, 1908.

EXHIBIT B.

RECEIPTS.		
Entrance Fees	$6,865.00	
Current Dues	45,036.73	
Past Dues	4,088.75	
Advance Dues	182.50	
Students' Dues	3,323.00	
Transfer Fees	460.00	
Badges	2,442.00	
		$62,397.98
Sales, Transactions, etc.	1,240.77	
Subscriptions, Proceedings	1,085.90	
Advertising	7,782.87	
Binding	71.00	
Exchange	20.65	
INTEREST:		
U. S. Govt. Bonds.	240.00	
Bank Balances	770.30	
Royalty	154.40	
		11,365.89
Total		$73,763.87

DISBURSEMENTS.		
Stationery and Printing	$4,559.27	
Postage	3,713.93	
General Expenses	2,460.69	
Meeting Expenses	2,436.60	
Section Meetings	2,749.82	
Badges	2,247.39	
Salaries	12,086.00	
Dedication	1,064.71	
Office Furniture	783.12	
		$32,101.53
PROCEEDINGS—TRANSACTIONS:		
Printing	13,324.23	
Salary	2,392.00	
Engraving	830.96	
Volumes	4,202.70	
Electrotyping	1,008.66	
Binding	512.60	
Express	793.89	
Advertising Commissions	1,959.02	
		25,024.06
LIBRARY:		
Furniture	290.80	
Librarians salaries	1,314.00	
Books and binding	425.49	
Library insurance.	60.90	
Moving expenses.	643.83	
Miscellaneous	165.96	
		2,900.98
United Engineering Society Assessments		6,533.33
Total		$66,559.90
Excess receipts over disbursements deposited in general fund		7,203.97
		$73,763.87

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

RECEIPTS AND DONATIONS FOR DESIGNATED PURPOSES, ALSO EXPENDITURES FOR YEAR ENDED APRIL 30, 1908.

EXHIBIT C.

RECEIPTS.	
Land, Building and Endowment fund, Donations, Interest, etc.	$14,335.85
Carnegie (Library) Fund, Interest	107.43
General Library Fund, Interest	7.15
Compounded Membership Fund	794.79
International Electrical Congress of St. Louis, 1904, Library Fund, on account of Principal	48.56
International Electrical Congress of St. Louis, 1904, Library Fund, on account of Interest	64.68
Mailloux Fund, Interest	30.00
Weaver Donation	100.00
Total	$15,488.46
Excess of Expenditures over Receipts (as below)	82,819.32
	$98,307.78

EXPENDITURES.	
Land, Building and Endowment Fund, on account of Mortgage	$90,000.00
Land, Building and Endowment Fund, on account of Interest and Expense	7,133.61
Carnegie (Library) Fund	468.84
Compounded Membership Fund	660.13
Mailloux Fund	20.20
Weaver Donation	25.00
Total Expenditures	$98,307.78

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

CONDENSED CASH STATEMENT.

EXHIBIT D.

Cash on deposit April 30th, 1907	$126,149.90	
Secretary's petty cash, April 30th, 1907	500.00	
	$126,649.90	
Receipts for general purposes, Exhibit " B "	73,763.87	
Receipts for designated purposes, Exhibit " C "	15,488.46	$215,902.23
Disbursements for general purposes, Exhibit " B "	$66,559.90	
Expenditures for designated purposes, Exhibit " C "	98,307.78	
Expended for New York City 4½% Bonds	12,677.50	$177,545.18
Balance on hand, April 30th, 1908		$38,357.05
On deposit for designated purposes, Exhibit " A "	$25,613.99	
On deposit for general purposes, Exhibit " A "	12,243.06	
Secretary's petty cash, Exhibit " A "	500.00	$38,357.05

PROPERTY ACQUIRED DURING THE YEAR.

Office Furniture and Fixtures	$783.12
Library Books and Binding	855.34

All outstanding bills due prior to May 1, 1908, have been paid.

Respectfully submitted for the Board of Directors.

RALPH W. POPE, *Secretary.*

New York, May 19, 1908.

REPORT OF THE LIBRARY COMMITTEE.

We beg to submit herewith our report giving the more important features of the growth and operation of the library for the year ending April 30, 1908; with a statement of the present condition of the several library funds and of the expenditures for the year.

The gifts to the Library through its members and others have numbered nearly 300 volumes together with a very large number of pamphlets as yet unlisted and not included in the statistics presented herewith. The total valuation of the books and pamphlets is now placed at $23,406.55 an increase of $855.34 for the year. The complete list of donors with the number of volumes presented by each is as follows:

DONORS

ADAMS, EDWARD D	11
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS	16
ANDREWS, W. S	4
AUDEL & CO., THEO	1
BOSTON TRANSIT COMMISSION	1
BOUCHER, W. J	9
BUREAU OF LABOR, CONNECTICUT	1
CAMP, W. M	1
CHEMICAL PUBLISHING COMPANY	4
CLAYTON & CRAIG	1
CROSSMAN, T. E	1
CUSHING, H. C., JR.	1
DEPARTMENT OF THE INTERIOR	1
DOREMUS, DR. CHAS. A	1
DRAKE & CO., FREDERICK	4
ELECTRICIAN PRINTING AND PUBLISHING COMPANY, LONDON	6
ENGINEERING NEWS PUBLISHING COMPANY	1
FLOY, HENRY	1
FOWLER, W. H	1
FRANKLIN, PROF. W. S.	1
GAUTHIER-VILLARS	1
GENERAL ELECTRIC CO	1
HAMMOND, R	1
HENLEY PUBLISHING COMPANY, N. W	2
HERING, CARL	2
HOBART & ELLIS	1
JENKS, W. J	1

KANSAS GAS, WATER, ELECTRIC LIGHT & STREET RAILWAY ASSO	1
LIBRARY OF CONGRESS	1
LINDSAY, C. E	1
LOCKWOOD, THOMAS D	1
MCGRAW PUBLISHING COMPANY	39
MACMILLAN COMPANY, THE	7
MAILLOUX, C. O	11
MARTIN, T. C	1
MORTON, DR. WM. J	1
MUNICIPAL OWNERSHIP PUBLISHING BUREAU	4
NATIONAL CIVIC FEDERATION	3
NEW YORK EDISON COMPANY	2
OHIO ELECTRIC LIGHT ASSOCIATION	2
POOLE, CECIL P	2
PUBLIC SERVICE COMMISSION FOR THE FIRST DISTRICT	28
RAILROAD GAZETTE	2
SCIENTIFIC PUBLISHING COMPANY	2
SCRIBNER'S SONS, CHARLES	1
SHELDON, DR. SAMUEL	1
SPON AND CHAMBERLAIN	5
U. S. NAVAL INTELLIGENCE OFFICE	6
UNIVERSITY OF ILLINOIS	1
VAIL, J. H	6
VAN NOSTRAND, D., & CO	2
WOLCOTT, TOWNSEND	1
WEAVER, W. D	66
WESTERN UNION TELEGRAPH COMPANY	1
WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY	3
WHITTAKER & CO	4
WILEY & SONS, JOHN	6
WYNKOOP, H. S	1

The general statistics of the Library and its valuation are shown in the following tabulation:

STATISTICS OF LIBRARY, MAY 1, 1908

Source	Titles	Volumes	Pamphlets	Valuation
Report of May 1, 1907	7649	11186	565	$22,551.21
PURCHASES:				
Mailloux Fund	4	11		20.20
Institute Appropriation	82	84		210.14
Weaver Fund	3	47		25.00
Periodicals	160	253		506.00
GIFTS:				
Edward D. Adams	3	11		39.00
From all other sources	75	236		55.00
Totals including duplicates	7976	11828	565	$23,406.55
Duplicates	308	609		824.74

In the following table are given the figures for the total valuation of the library property including $290.80 expended for new stacks during the past year:

Total Valuation

Books	$23,406.55
Stacks	1,761.05
Furniture, Catalogues, Cases, etc	208.28
	$25,375.88

The following tabulations give the state of the five funds from which the Library Committee is entitled to draw:

Donations (General Library Fund)

Dr.		Cr.	
Balance May 1, 1907	$237.00		
Interest May 1, 1908	7.15	Unexpended	244.15
	$244.15		$244.15

Carnegie Fund

Dr.		Cr.	
Balance May 1, 1907	3529.60	Wheeler Bibliography	468.84
Interest May 1, 1908	107.43	Unexpended	3168.19
	$3637.03		$3637.03

Mailloux Endowment Fund ($1000)

(Proceeds for the maintenance of certain sets of periodical publications)

Dr.		Cr.	
Balance May 1, 1907	$ 7.55	Subscriptions	20.20
Interest May 1, 1908	30.00	Unexpended	17.35
	$37.55		$37.55

International Electrical Congress of St. Louis, 1904, Fund

(Principal)

Principal May 1, 1907	$2097.56
Additions to Fund	48.56
	$2146.12

(Proceeds)

(Available for the purchase of International Electrical Literature)

Dr.		Cr.	
Interest accrued prior to May 1, 1907	42.54		
Interest to May 1, 1908	64.68		
	$107.22	Unexpended	$107.22

Weaver Fund

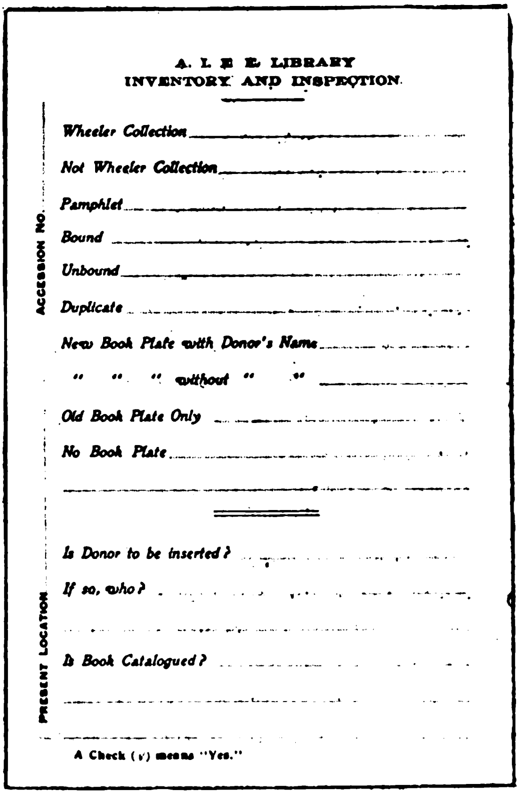
(For early and out of print electrical literature)

Dr.		Cr.	
Amount of Fund	$100.00	Expended	$ 25.00
		Unexpended	75.00
			$100.00

INSTITUTE APPROPRIATION ACCOUNT

Dr.		Cr.	
Appropriation for Maintenance for Year ending October 31, 1907	$3500.00	Insurance	$ 60.90
		Salary, Librarian " Assistant	1314.00
		Binding	215.35
		Supplies	41.62
		Subscriptions	40.74
		Express and Postage	6.90
		Books	210.14
		Fixtures	290.80
		Miscellaneous	76.70
		Moving	643.83
		Unexpended	599.02
			$3500.00

The above table shows total expenditures of $2900.98 out of the entire appropriation of $3500.00. The salary account is increased nearly $500 by reason of the additional attendance made necessary by keeping the Library open evenings until nine o'clock. The binding of many volumes of periodicals left over from previous years in an unbound form has increased this item of expense from $135.00 to $215.00. "Fixtures," which



A. I. E. E. LIBRARY
INVENTORY AND INSPECTION

ACCESSION NO.

Wheeler Collection ____________

Not Wheeler Collection ____________

Pamphlet ____________

Bound ____________

Unbound ____________

Duplicate ____________

New Book Plate with Donor's Name ____________

" " " without " " ____________

Old Book Plate Only ____________

No Book Plate ____________

____

Is Donor to be inserted? ____________

If so, who? ____________

____

Is Book Catalogued? ____________

____

____

PRESENT LOCATION

A Check (✓) means "Yes."

cost $290 this year against $73 last year, includes new book stacks and shelving. It should also be pointed out that the entire expense of moving the Library from Liberty Street to the new Engineers' Building, $643.83, is included in the disbursements for this year.

General Inventory and Inspection

It has been found necessary to make a complete inventory and inspection of the books and pamphlets on the shelves, preparatory to making a complete subject catalogue which will include all of the material possessed by the library. This work has progressed continuously for several months by a personal examination of each book and pamphlet, a permanent record being made on cards to show the exact condition of each item with relation to the library records. The card reproduced herewith shows the character of the information obtained by this inventory.

When this work is completed the library will not only be in excellent and most satisfactory and well arranged condition as regards many of the minor details that have not heretofore had proper care, but will also be well prepared for the larger and more important undertaking of producing the card catalogue which shall induce all of the electrical literature now on the library shelves. The production of an exhaustive catalogue of this nature is now under consideration and it is planned to include in this catalogue a detailed index to several important sets of electrical periodicals and collections of electrical literature among which may be mentioned the Transactions and Proceedings of the American Institute of Electrical Engineers, the *Journal* of the Institution of Electrical Engineers, London, and the *Transactions* of the International Electrical Congress of St. Louis, 1904.

Important Gifts

Among the gifts deserving of special commendation may be mentioned a fund of $100 given by Mr. W. D. Weaver to be applied to the purchase of early and out of print electrical books. Mr. Carl Hering, a former president of the Institute, has offered to present to the Library a collection of books relating to meetings of various International Electrical Congresses with which he has at various times been associated. The committee has accepted this gift, but the books have not yet been turned over to the library. The New York State Public Service Commission for the First District has very kindly presented to the Library an almost complete set of the reports and records of the Commission and its predecessor, the Rapid Transit Commission of the City of New York. These records include many drawings and plans relating to the construction of the New York City subways. Mr. Edward D. Adams has again met the expenses for the subscription and binding of the *Proceedings* and *Transactions* of the Royal Society of London, and for the additional volumes of the International Catalogue of Scientific Literature. He has also kindly consented to bear the expenses of binding the entire set of volumes of this important set of scientific records. The proceeds of the fund presented by Mr. C. O. Mailloux have again been drawn upon to furnish the yearly continuation of four important periodical sets originally presented by Mr. Mailloux to the Library. Mr. W. S. Andrews has set a worthy example to other members of the Institute by presenting four items of very great historical interest including an original manuscript written by Mr. Thomas A. Edison in 1883, and an original note book compiled by Mr. Andrews from 1881 to 1885 while engaged in designing and installing Edison lighting plants. Mr. J. H. Vail has also presented several important books and pamphlets of historical interest chiefly relating to the early days of electric lighting in the United States.

COMPLETION OF SETS

The Library has been very fortunate in being able to complete several important sets which heretofore it possessed in very incomplete form, among these may be mentioned:

American Street Railway Investments; Vols. 1 to 14.
Boston Transit Commission; Annual Reports, Vols. 1 to 13.
New York Public Service Commission for the First District; complete set of reports.
American Bell Telephone Company and American Telephone and Telegraph Company; a complete set of annual reports, 1881 to 1907.
Western Union Telegraph Company; a complete set of annual reports, 1874 to 1907.
General Electric Company; a complete set of annual reports, 1893 to 1908.
New York Edison Company and its predecessors; a complete set of annual reports.
New York State Railroad Commission's Reports; a complete set from 1883 to 1904.
American Street Railway Directory and its successors. This set has been made practically complete.
American Electrical Directory and its successors to date. This set has also been made practically complete.

EARLY PERIODICALS

Mention should also be made of a long list of early electrical periodicals recently purchased at a small cost. Nearly all of these periodicals were transient in their nature but all are of great value to the Library from their historical importance. A complete list of the titles is here given:

Telegraphers' Advocate, New York.
Electrical and Street Railway Reporter.
Electrical Doings, New York.
Electric Telegraph and Railway Review, London.
Boston Telegram.
Electrical Era, St. Louis.
Electrical Magazine, Washington.
The Wire, New York.
Popular Electric Monthly, Chicago.
Phonogram, New York.
Electrical Literature, Chicago.
Whipple's Electric Reports, Detroit.
Elektron, Boston.
Electricity, Cincinnati.
Electrical Industries Directory of Central Stations, etc., Chicago.
Directory of Electric, Cable and Horse Railways in the U.S. and Canada, New York.
Electrical Progress and Development, Boston.
Electrical Worker.
Street Railway News, New York.
Street Railway and Electrical News, St. Paul and Minneapolis.
Electrical News, Boston.
Electric Railway Advertiser, Boston.
Electricity and Railroading, Boston.
The Telephone, Chicago.
Electrical Northwest.
Electrical Items, New York.
Miscellaneous Bulletins of Electrical World, issued at the National Electric Light Association meetings.

A small collection of books has recently been purchased from the library of Mr. J. B. Stearns, one of the early inventors of telegraph apparatus. From this source a number of important items have been obtained not already in the library's collections.

EXCHANGES

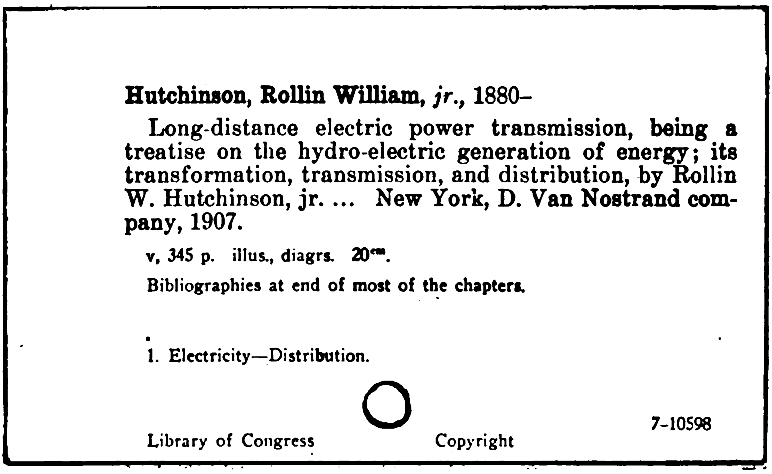
An effort has been made to increase the facilities of the Library by adding to the already large list of exchanges received from all parts of the world. Working in harmony with the other two Engineering Societies whose libraries are located with ours, a complete list of exchanges was made up numbering in all 561 titles. This long list of engineering periodicals has already been added to by the solicitation of other exchanges, and it is hoped at an early date to make the resources of the library in this particular far superior to those of any other engineering collection in the United States.

RECENT BOOKS

An attempt has also been made during the past year to increase the facilities of our library by the addition of modern and recently published electrical books and a large part of our purchases, aside from those made to complete deficiencies in existing sets have been along these lines.

LIBRARY OF CONGRESS CARDS

In the cataloguing of recent books the use has been made of the Library of Congress printed cards. These are obtained from the Librarian of Congress at a nominal cost and when received are practically ready for use in the card catalogue. A sample of these cards is herewith given.



Hutchinson, Rollin William, *jr.,* 1880–

Long-distance electric power transmission, being a treatise on the hydro-electric generation of energy; its transformation, transmission, and distribution, by Rollin W. Hutchinson, jr. ... New York, D. Van Nostrand company, 1907.

v, 345 p. illus., diagrs. 20^{cm}.

Bibliographies at end of most of the chapters.

1. Electricity—Distribution.

7-10598

Library of Congress Copyright

OPENING OF THE LIBRARY ON WEEK DAY EVENINGS

Through the joint action of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, the libraries of all three societies were opened to the public every evening until nine o'clock, except Sundays and legal holidays, beginning November 1, 1907. This has necessitated considerable additional expense for attendance, light, heat, elevator service, etc. The total attendance both day and evening for November, 1907 to April, 1908 is shown in the following table, (the attendance for November not being divided):

	Day	Evening
November 1907 (total)	570	
December, 1907	275	371
January, 1908	526	248
February, 1908	439	241
March, 1908	417	203
April, 1908	403	210

BIBLIOGRAPHY OF WHEELER COLLECTION

This work has been carried on this year under the direction of a special committee appointed by the Board of Directors so that no report by the Library Committee is called for.

GIFTS DESIRED

The Library Committee solicits from members or others gifts of portraits, photographs, drawings and engineering sketches as well as books and pamphlets, many of which would be of great value to the resources of the library. Many of these can only be obtained through the cooperation of members.

Respectfully submitted,

The Library Committee
EDWARD CALDWELL,
Chairman
MORGAN BROOKS
MAX LOEWENTHAL
F. A. SCHEFFLER
PHILIP TORCHIO

A paper to be presented at the 25th annual convention of the American Institute of Electrical Engineers, Atlantic City, N. J., June 29, 1908.

Copyright 1908. By A.I.E.E.

(Subject to final revision for the Transactions.)

THE EVOLUTION OF ENGINEERING

PRESIDENT'S ADDRESS

BY HENRY GORDON STOTT

Eighty years ago Thomas Tredgold defined engineering as " The art of directing the great sources of power in nature for the use and convenience of man." Progress in engineering has been greater in the eighty years which have elapsed since this definition was made than in the previous period of 4500 years beginning with the first great, tangible piece of engineering, the pyramid Cheops.

The question naturally arises: does this definition hold good to-day? Is it broad enough? If not, how can we better define the engineer's sphere of activity? If we accept Tredgold's definition as our standard, will we reach the position in society which belongs to us by right of education, achievement, and highly developed power of logical deduction from facts observed and investigated?

Engineers may be divided into two gene al classes: first, those who believe that the engineer should be restricted to a specific vocation, such as electrical, steam, hydraulic, pneumatic, or sanitary engineering, etc; second, those who wish to see him take his place not only as an engineer but also as a public-spirited citizen and leader.

The great amount of specialization which obtains in electrical engineering to-day is instanced in the subdivisions now found, such as telegraphy, submarine telegraphy, telephony, wireless telegraphy, railway signaling, underground cable engineering, high-tension transmission, electric lighting, electric railways, alternating-current generator designing, direct-current generator designing, railway motor designing, converter designing, transformer designing, railway, lighting, telegraph, and telephone switchboard engineering, etc.

The score or more of divisions of electrical engineering which exist to-day are the necessary outcome of the consolidations of manufacturing and other interests into a few large concerns: they are the natural economic results of competition. As these consolidations have undoubtedly resulted in greater efficiency and, therefore, in reduced cost of production, there is every reason to expect a continuance of this evolution from the simple factory manufacturing only one article, to the complex one which manufactures many things. In such a factory it is manifest that as soon as any one article is called for in sufficient quantities to require the entire time of the man in charge, a new department will be formed and another subdivision of engineering created. In exactly the same way we will find consulting engineers who specialize on cables only, others on illumination, etc., and on any pursuit which is of sufficient importance to claim undivided attention. This process of segregation is evidently one of infinite application in all pursuits, tending strongly to an ever narrower development of the individual, but at the same time increasing his efficiency to a maximum in his own particular specialty. This increase in efficiency, however, will cease if the engineer becomes so highly specialized as to ignore the necessity of keeping in touch with the entire sphere covered by his company, as the evolution of each branch must be synchronized with that of all.

The other class, to which the term " second " has been arbitrarily assigned merely to indicate its numerical inferiority, embraces all those who have broadened their field through self-education, experience, opportunity, and natural adaptability for administrative work. The term self-education is used advisedly, as both classes are assumed to start with the same technical training, and as a matter of actual fact the second class almost invariably evolves from the specialists.

The engineer who is called upon to report on a projected rail road, for example, must also be a student of political economy in order to give proper weight to the various economic problems which must be first studied before he reports upon the advisability of even making a survey. He should be thoroughly familiar with the general organization of the state governments through whose territory the road may run, as well as have a general knowledge of their laws affecting corporations, franchises, etc. In order efficiently to carry out his work, it will be necessary for him to come in contact with various officers of the state and city governments, so that he should be a man of general and broad culture, capable of meeting any one with credit to himself and the company he represents. Lastly, if he is personally acquainted with some of the more important state or city officials, or the members of the legislature, his work may be greatly facilitated and his services be just so much more valuable to his employer.

Tredgold's definition of engineering evidently did not contemplate this enlargement of the engineer's sphere, and it is only by a natural process of evolution that some have reached this stage.

The second class is necessarily a restricted one, as, whilst the legitimate field of work of the engineer is extremely broad and almost unlimited, yet as a rule he has apparently decided to keep in the background and only come to the front when called. The result of this policy is that when the opportunity comes, the engineer is taken at his own valuation and passed over for others who, whilst not suffering from modesty, are lacking in engineering education and experience, and therefore are forced to call in engineers (to act in a subordinate position) to supply the incumbent's deficiency in the qualifications necessary for the office.

A good illustration of this policy is furnished in the appointments made on two state public service commissions, in which the ten offices are filled by gentlemen whose occupations had been as follows; six lawyers, two manufacturers, one political office-holder, and one engineer. These commissioners have control of all matters pertaining to public service corporations; and as their functions are of an inquisitorial and critical character on subjects which are almost exclusively of an engineering nature, it is quite evident that their lack of engineering knowledge must be a severe handicap, not only to them but much more so to the state that employs them, and lastly, but not least, to the company or corporation suffering from their well-meant but misdirected efforts.

What is the cause of this anomalous situation. Is it entirely the fault of the executive who makes these appointments? Has not the whole body of engineers some share in the blame? We have seen that there is to-day an inherent tendency to specialization in engineering, and that by far the greater number of our members are becoming experts in one or two subjects only, and that comparatively few attempt to keep in touch with the more general aspects of engineering. This condition is caused not so much by a lack of willingness as by lack of time and opportunity.

This centrifugal force acting on our profession has fortunately a nearly equal centripetal one which is found in such societies as the American Institute of Electrical Engineers, in which all can once more be brought back to a common centre on the common ground so clearly described in our Constitution, which says that the object of the American Institute of Electrical Engineers " shall be the advancement of the theory and practice of Electrical Engineering and of the Allied Arts and Sciences."

The conference held in Washington, D. C., last month, which was called by President Roosevelt to consider what steps should be taken to conserve our natural resources, was preceded by a series of conferences held by the presidents of the four national engineering societies, at which a series of broad resolutions were drafted and afterwards presented at the conference as representing the opinions of 20,000 American Engineers.* The Committee on Resolutions presented a very able report to the conference, embodying practically everything we had recommended, with one exception, as that particular item had already been covered in a bill introduced into Congress. The resolutions were unanimously adopted.

Several important deductions may be made from this incident. First, united recommendations after careful investigations of facts by engineers, on any public question involving engineering problems, will be not only courteously received but welcomed and highly appreciated by our state and federal governments. Secondly, the facts presented at this Conference were of such a far-reaching and important nature that every member of this Institute should feel it is his duty carefully to study the able papers presented, and to further in every way possible the policy of preserving our natural resources. In this we all can unite no matter whether we are specialists or general engineers. Thirdly, coöperation on the part of the four national engineering societies is absolutely essential to success in any movement of this kind; and, as a corollary, success is certain if we coöperate. Fourthly, if engineers are to take the place in society which belongs to them by right of education and training, they must take an active part in matters of general policy or civic interest, no matter how remote these matters may seem from Tredgold's definition of engineering.

---

* PROCEEDINGS A. I. E. E., June 1908, Section I, p. 5.

After nine of the ten commissioners names previously referred to we can find the significant words, bracketed," active in politics. " Is there no lesson for engineers here? Is it not their civic duty to the state and nation to take a more active part in public affairs, giving of their special knowledge freely, as may be required of them, at the same time insisting upon the same high ideals of faithful, honest, and loyal performance of duties in public life as they have been accustomed to in their every-day work as engineers?

These suggestions are clearly outside the scope of this Institute as set forth in its Constitution, and in all probability would be pronounced heretical in any of our engineering societies, so that to carry them out it may become necessary to organize a new society in which membership would be limited to members of the four national engineering societies, and whose object would frankly be to use all legitimate political methods to influence legislation on matters affecting engineering; for example, such as carrying out the recommendations of the Conference on Preservation of Natural Resources, or the application of the principles of political economy to the laws affecting public utility commissions, etc.

An enormous amount of work must be done in order to induce our state and national legislatures to pass the necessary legislation in regard to preservation of our natural resources. No body of men is so peculiarly qualified to advise on these matters as that composed of engineers. Such a society could with propriety take up the consideration of many problems of which the public now hears only one side, and that usually the demagogue's, simply because the engineer has maintained an attitude of reserve. His silence is frequently mistaken for either assent or guilty knowledge, when in nine cases out of ten he remains silent either from a mistaken policy, dictated possibly by his employer, or because he considers it undignified to reply to criticism.

Belonging to a society whose object it is to guide and instruct public opinion in engineering matters, this feeling would soon disappear, and the benefit of coöperation among engineers in this respect would make this society's influence felt in every city and state in the country. Our large corporations and manufacturers are realizing as never before the benefit of publicity departments, not only for advertising purposes, but for the purpose of disarming adverse criticism by a calm statement of facts.

In conclusion, let us remember that if we wish to progress and assume our proper place in the world, we must be aggressive and not passive in allegiance to our engineering societies; that the day is long past for hiding our light under a bushel, and that instead of Tredgold's definition of engineering, the following more correctly expresses the position of the engineer to-day:

Engineering—The art of organizing and directing men, and of controling the forces and materials of nature for the benefit of the human race.

Presented at the Conference on the Conservation of Natural Resources, White House, Washington, D.C., May 13-15, 1908.

Copyright 1908. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

CONSERVATION OF POWER RESOURCES

BY H. ST. CLAIR PUTNAM

Without disparaging other aspects of our progress, it is not too much to say that our time is preeminently the age of power. This applies to the world at large, but especially to the United States. Our population is increasing with unprecedented rapidity, but our mineral production is increasing so much more rapidly that some have called this the age of metal. Steel, copper, and wood are combined in mechanical devices at a rate increasing more rapidly than ore production, so that others have characterized this as the age of the machine; yet that aspect of modern life which most impresses the student of progress is the increasing use of mechanical power through the development of prime movers and the utilization of new power sources. Rapidly as our population advances, it is outrun by metal production, and that in turn by machine building; yet our most rapid progress —the feature in which our advancement exceeds all others— is in the development and use of power.

Historical division. Historically considered, the utilization of our power resources has undergone three characteristic phases of development.

In the first, power was produced directly by natural forces such as falling water and wind and its use necessarily was limited to those places where these natural forces were found. This led to the early manufacturing establishments of New England grouped about easily available water powers. This might be called the period of water powers, and in this country it held ascendency in the manufacturing industries until about 1870.

The second phase was characterized by the development of the steam engine which rendered practicable the utilization of the stored energy in fuel as a source of power. During this period the development of coal mines and rapid growth of our railway systems imparted a tremendous stimulus to commercial enterprise. Proximity of water powers was no longer controlling, and factories were established at points selected by reason of the availability of raw material, labor, transportation facilities and markets, as well as power supply. As in the first period, however, the power necessarily was used where developed and the size of the plant was limited to the requirements of the individual user.

*Electric power.** Electrical transmission of power is the new art which now is resulting in another and radical change in methods of utilizing our power resources, permiting, as it does, development whether by water power or by steam at points most convenient and economical, and transmission to the consumer in form adapted to great variety and convenience and use. This new development in applied science calls for reappraisement of the sources from which our power is derived. The size of the power plant is no longer limited to the requirements of the individual user but the power for entire communities can be supplied from a single station. The enlargement of this field of work newly opened by the electric transmission of power from great distances is now in active and practical development. As a result rapid changes are taking place in the methods of using power. New economies are possible of accomplishment and the resulting effect upon the conservation and utilization of our power resources is of the greatest importance.

Fuel supply. Where power is developed from the combustion of coal, wood, oil or gas, our natural resources as such are destroyed and they cannot be replaced, excepting to a limited extent in the case of wood and similar products. The supply of natural oil and gas is limited and uncertain and the amount available is required for special industries. The coal production of the United States for the year 1906 was 414,157,278 tons; for 1907, about 450,000,000 tons. If the production of anthracite coal is continued at only its present annual rate the supply will be exhausted in 60 or 70 years. Since the beginning of our coal industry the total production has doubled approximately every ten years. Assuming that this rate of increase cannot be maintained, but will become constant in about 150 years, it is estimated that the supply of bituminous coal will be exhausted in approximately 700 years.* But that the coal production should become constant even 150 years hence, implies that our industries must become stationary, unless other power resources are found. We cannot look forward to such a condition with equanimity. Without coal our domestic and industrial life are inconceivable, and our existence in great cities and crowded communities is impossible unless a substitute is devised. The future welfare of the nation requires that all practicable means be employed for the conservation of the supply of coal.

---

* Electricity, of course, is not a source of power—it is simply the agent by which energy developed from fuel and water is transmitted to the mechanism which utilizes it. In speaking of electric power, therefore, it must be borne in mind that such power is always produced primarily by water wheels, turbines, steam engines, or gas engines. With reference to their source, therefore, we have only water power and fuel power to consider, but with reference to application it is convenient and instructive to compare water power, steam power and electric power; the two former being applied directly through mechanical means to the work, while the last named has its origin in one or the other of the former and is applied through motors.

Available water powers. Where power is derived from water, winds, and tides, only energy otherwise wasted is used. The energy thus extracted is added to our assets instead of being a permanent loss as is the case with the combustion of coal. It is now feasible and practicable to develop water powers, whereever located, for electric power. In the aggregate the available water powers of the nation greatly exceed the present power requirements, but unless there is some curtailment in the rate of our development, our water power resources, while being of great magnitude, will not of themselves solve the problem of our future supply of power. The amount of water power available in the United States is not known. Some partial estimates have been made, but these are necessarily approximate, as exact figures can be obtained only after careful survey and study not only of the existing physical conditions, water flow, and available reservoir capacity, but of the practicable auxiliary steam power that can be profitably installed. The power of Niagara has been estimated, by Professor W. C. Unwin, at 7,000,000 h.p. A partial estimate of the water powers of the upper Mississippi river and tributaries places the available water power at about 2,000,000 h.p. The southern Appalachian regions can furnish a minimum of nearly 3,000,000 h.p.* Both of these estimates can be greatly increased by including the use of regulation reservoirs and auxiliary steam plants. The water powers of New England are more fully developed than elsewhere in the country, though much remains yet to be done. In the Rocky mountains and the far west there are immense water power possibilities; in the state of Washington alone there are 3,000,000 h.p. available;† and Governor Pardee estimates that the streams of northern California are capable of producing 5,000,000 h.p. Even approximate data upon which to base an estimate of the total amount of available water power in the country are lacking, though a good start toward collecting them has been made by the Geological Survey, with the limited means at its disposal. It is probable that the water power in the United States exceeds 30,000,000 h.p., and under certain assumptions as to storage reservoirs this amount can be increased to 150,000,000 h.p. or possibly more. Much depends upon whether regulation reservoirs and reserve steam plants are included in the estimate. Both have been demonstrated to be practicable, and undoubtedly should be considered in any estimate made of the available water power resources of the country.

---

* "How long will our coal supplies meet the increasing demand of commerce?" by Edward W. Parker, U. S. Geological Survey. Presented before the American Society of Mechanical Engineers, 1907.

Using the smaller figure of 30,000,000 h.p. as an illustration, to develop an equal amount of energy in our most modern steam-electric plants would require the burning of nearly 225,000,000 tons of coal per annum, and in the average steam engine plant, as now existing, more than 650,000,000 tons of coal, or 50%, in excess of the total coal production of the country in 1906. At an average price of $3.00 per ton it would require the consumption of coal costing $2,000,000,000 to produce an equivalent power in steam plants of the present general type.

The supply of water power is limited, however, when the rapid rate of increase in our power requirements is considered, and great care, therefore, must be exercised to insure the preservation of our water power resources and to secure the maximum practicable development.

---

* "Water Powers of the Upper Mississippi and Tributaries," and "Water Powers of the Southern Appalachian System," by M. O. Leighton, Chief Hydrographer, U. S. Geological Survey.

† Computed by F. G. Moorhead, in *The World's Work*, April 1908, p. 10091.

Total power used in United States. Using the data furnished by the census returns of 1900, 1902, and 1905 as a basis and applying the prevailing rate of increase in the industries included in these reports, and adding an equivalent amount for the steam railroads, it is estimated that the total installed capacity of prime movers in all our land industries for the year 1908 approximates 30,000,000 h.p.[A] (Fig. 1.)

The average load on steam and other engines is much less than their rated capacity, and, owing to the overlapping of loads, it is probable that the total average load does not exceed one-third or one-quarter of this amount.

Rate of increase. During the last thirty years the total amount of power used in our manufactories and other industries, as recorded by the census, has doubled approximately every ten years. The fact that substantially the same rate of in-

---

[A] The following table compiled from the latest census returns gives the installed capacity of prime movers in the United States in the industries named at the dates mentioned:

	Installed horse power.
Manufactures, census 1905	12,765,594
Mines and Quarries, census 1902	2,753,555
Street Railways, census 1902	1,359,289
Electric Light and Power Stations, census 1902	1,845,048
Telephones, Telegraph and Fire Alarm Systems, census 1902	3,148
Custom Flour, Grist and Saw Mills, census 1900 (omitted from census 1905)	883,685
Steam Railroads, data from Statistics of Railways, 1905, equivalent power	3,750,000

These figures include prime movers only. Duplications in the way of electric, water and air motors and rented power have been omitted. The equivalent power used by the steam railroads is based upon the result of calculations made by Lewis B. Stillwell and H. St. Clair Putnam in a paper presented by them to the American Institute of Electrical Engineers, January, 1907, " On the Substitution of the Electric Motor for the Steam Locomotive," and represents the installed power house capacity required for their electric operation in the year 1905. Based upon maximum draw-bar pull, the power of the 46,743 steam locomotives in the United States (1904) averages 600 horse power (census 1905) but the power developed when averaged over the entire year approximates only 40 horse power. In order, therefore, that the estimate of total power in the United States should not be misleading, the power used by our steam railways has been taken at a figure that is comparable with the installed power in other industries as, for example, in electric railways where the installed capacity in the power houses has been taken rather than the rated power of the motor equipment, which is many times greater than the power house capacity required for their operation.

crease has existed in coal production, railroad gross earnings, freight ton-mileage, passenger mileage, and the value of agricultural products, as well as in total power consumption, is a striking demonstration of the close interrelation and mutual dependence of these great factors which, in the aggregate, measure the industrial progress of the nation.

We cannot foretell how long the present rate of increase in our industrial enterprises will continue. This will be determined by the general laws which govern industrial development

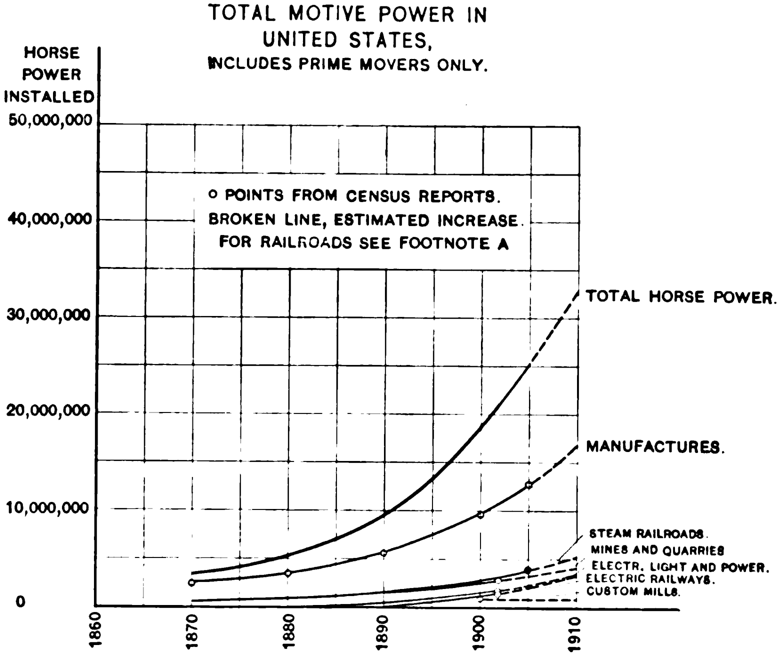


FIG. 1

and by the increase in wealth. It is clear, however, that if our power resources are exhausted or wasted the result will be disastrous.

Relative use of steam, water power, etc. Of the total estimated power at present produced by prime movers, about 26,000,000 h.p. is produced by steam engines, (Fig. 2) 3,000,000 h.p. by water motors, (Fig. 3) and 800,000 h.p. by gas and oil engines, (Fig. 4). These figures emphasize the present position of the steam engine in our industrial development and the relatively much less important place now occupied by water power, (Fig. 5).

Growth of electrically applied power. Of the total 30,000,000 h.p., including the railroads, used in the country, it is estimated that 9,000,000 h.p., (Fig. 6) or 30 per cent., is now utilized electrically (Fig. 7).* This highly remarkable growth has been accomplished in 25 years. The use of electric power at the present time is being doubled approximately every five years, as contrasted with the phenomenal doubling of the total power every 10 years. If the present rate of increase is maintained, electrically applied power will equal or exceed the power mechanically applied in 1920. This great growth is due to the convenience, earning capacity, and economy resulting from

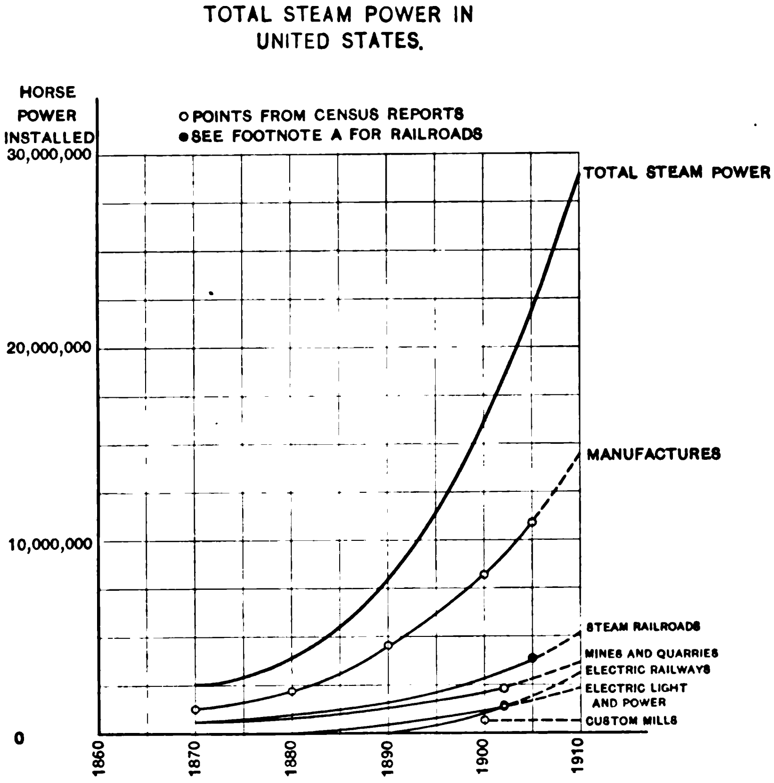


FIG. 2

---

* This does not include the electric power generated in isolated plants and used for other purposes than manufacturing. These plants are not included in the census reports, and while they are individually small the aggregate electric power developed is large.

the use of electrically applied power. The significance of this remarkable increase in the use of electric power in manufactures and other industries lies in the market thus provided for the utilization of our water powers wherever located and whatever their magnitude.

Economies due to electric power—steam power. Where coal is the source of power, electric transmission and distribution greatly reduce the amount burned to perform given mechanical work. This results from the substitution of a few large and highly efficient boilers and engines for a larger number of relatively small and uneconomical ones and from the introduction of plant economies and skill in operation not attainable in the smaller plants. A material saving is effected also in the application of the power directly to the work through motors instead of indirectly through inefficient countershafting and belting.

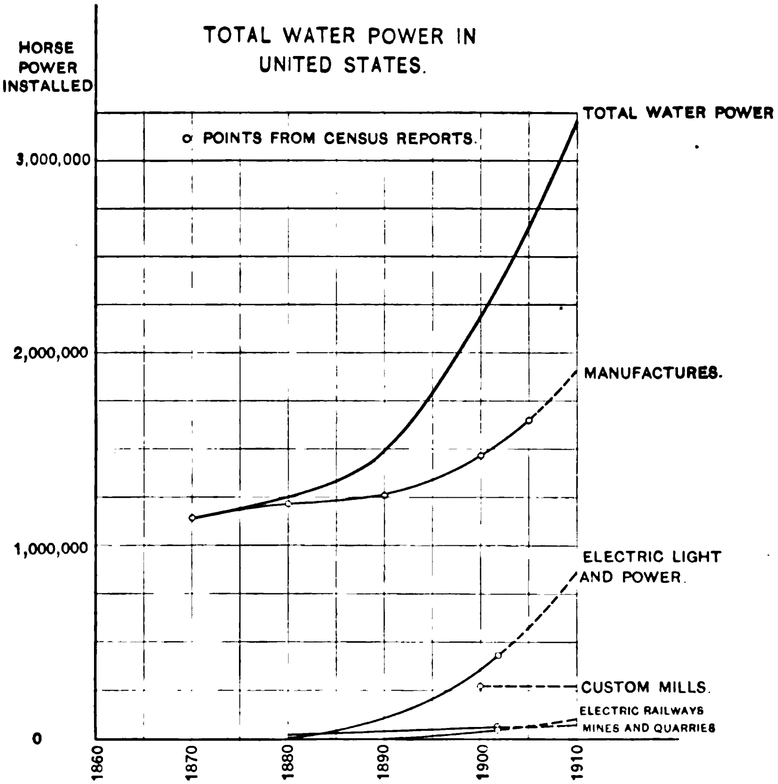


FIG. 3

A further material gain also results from the fact that a large plant carrying the load formerly carried, for example, by one hundred small plants is operated under conditions more nearly approximating uniformity of load and therefore at higher economy.

Greater economy can be obtained, even in our large plants, through the more general use of so-called fuel economizers, superheated steam, higher vacuum, and better combustion under the boilers. We may expect still higher efficiency from the development of larger boiler and engine units. These economizing appliances, which are relatively unimportant in small plants, become of great importance in large plants, and will have still greater influence on steam practice as the price of fuel increases and the cost of capital decreases.

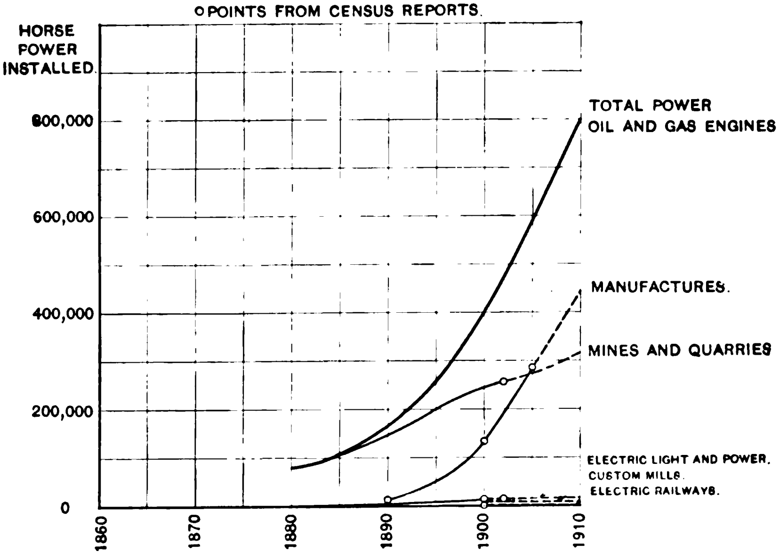


FIG. 4

Fuel economy of gas engines. This discussion would be incomplete without mention of the great possible fuel economy that may result from the use of gas and other similar engines. Though engines of this character antedate the use of the electric motor, their development has been slow, and they occupy a relatively unimportant place as power producers. The ordinary steam engine utilizes not more than four or five per cent. of the heat energy in coal, and our best modern steam electric plants show a heat efficiency not exceeding 10 or 12 per cent.* With the gas engine and producer gas the heat efficiency can be more than doubled, and still higher efficiency seems probable with higher compression or through the use of other possible improvements.† This is a most promising field for development

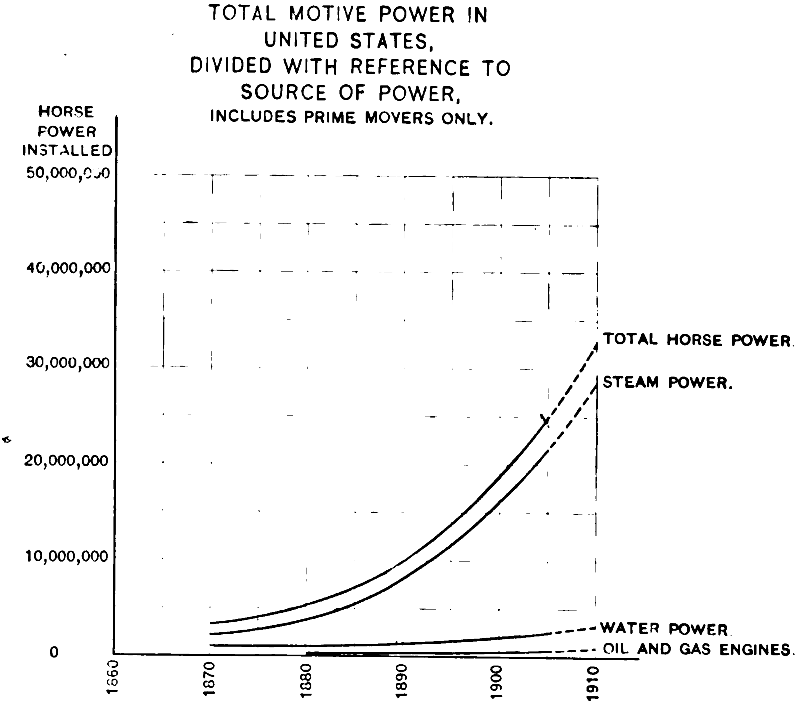


Fig. 5

and it is entirely possible that the gas engine may revolutionize our methods of using fuel for the production of power.

Beyond these gains, which may be considered well within the limits of possible attainment by present knowledge, there stands the theoretical prospect of still greater economies, the possibility of which cannot be denied so long as methods employed in developing energy from coal results in a waste of from 75 to 95 per cent. of the potential energy which nature has stored in the coal. But the science of the present time does not permit us to assume any radical increase in efficiency of fuel engines beyond the limits which I have indicated, and our only safe course is to base our estimate upon the progress of the present time with such reasonable allowance for improved economy as is dictated by recognition of progress of the art along lines now within the horizon of possible science.

---

* "Power Plant Economics," by Henry G. Stott, presented before the American Institute of Electrical Engineers, January, 1906.

† Report of F. W. Burstall to the Gas Engine Research Committee of the (British) Institution of Mechanical Engineers.

TOTAL ELECTRIC POWER IN UNITED STATES

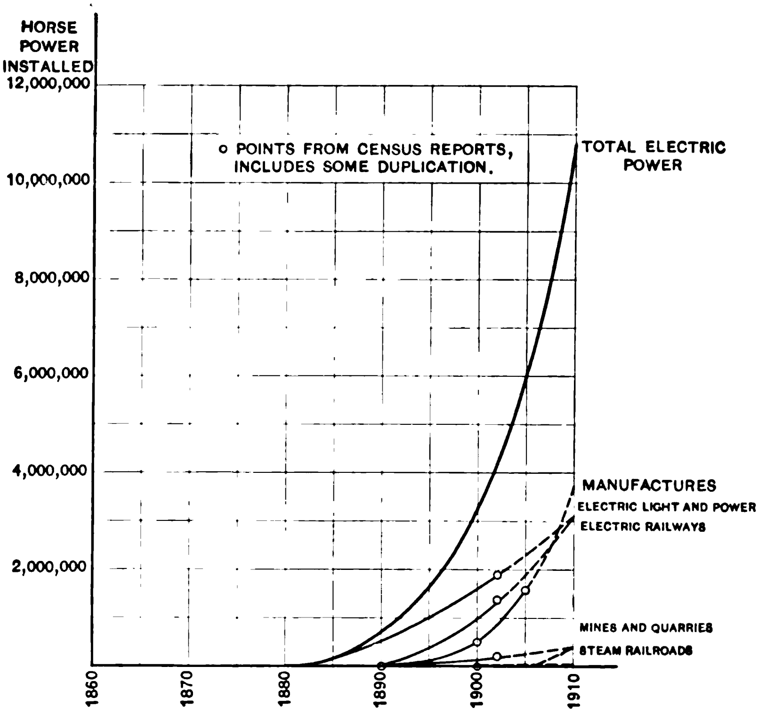


Fig. 6

Water power economies. Where water power is the source of supply, electricity promotes economy for reasons identical with the foregoing, except that absence of fluctuation of load is relatively less important, but the great gain which results from electric transmission is the utilization of water powers remote from power markets. Where several water powers along a stream are developed, it becomes possible to utilize, in conjunction with the larger and more cheaply developed powers, others which, considered independently, could not be utilized to advantage.

Applications of electric power—manufactures. Prior to 1870 the use of water power in manufactures exceeded that of steam power. Water power expressed in percentage of the total power employed has since steadily declined, falling from 48.3 per cent. in 1870 to 11.2 per cent. in 1905. (Fig. 8.) During the corresponding period steam power increased from 51.8 per cent. in 1870 to 78.2 per cent. in 1900. The census of 1900 showed a marked falling off in the rate of increase in the percentage of steam power used as compared with the rate prior to 1890, and this was accentuated in the census of 1905,

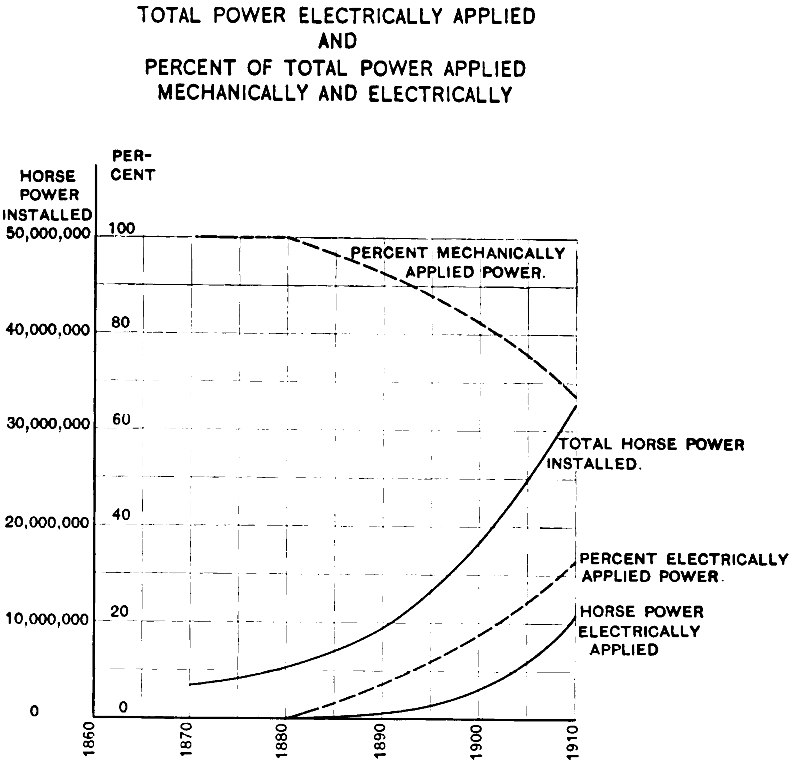
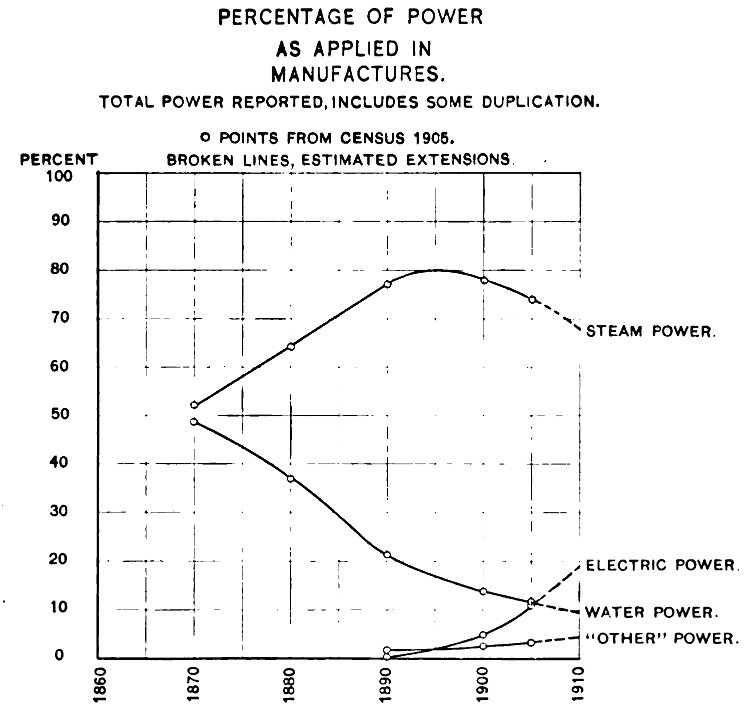


Fig. 7

when the percentage of steam power fell to 73.6 per cent. of the total. This check to the ascendency of directly applied steam power was due to the introduction of electric power. In 1890 electric power was negligible. In 1900 it constituted 4.8 per cent. of the total. In 1905 this had increased to 11.8 per cent.—a marvelously rapid growth when the aggregate increase of over 1,000,000 h.p. in five years is considered. If the present rate of increase prevails until 1910, electric power will have



PERCENTAGE OF POWER
AS APPLIED IN
MANUFACTURES.
TOTAL POWER REPORTED, INCLUDES SOME DUPLICATION.

O POINTS FROM CENSUS 1905.
BROKEN LINES, ESTIMATED EXTENSIONS.

FIG. 8

reached 18 per cent. of the total and steam power will have dropped to 68 per cent. If the same rate of increase is maintained until 1930, electric power as applied to the manufacturing industries will exceed the amount of steam power applied direct.

Other industries. The tendencies illustrated by the changes that have taken place in the methods of utilizing power in manufacturing, apply generally to other industries. The increasing use of power is phenomenal; the steam engine as a source of power is thus far paramount in them all, but the percentage of electrically applied power is increasing at nearly double the rate of increase of the total power used.

Electric lighting. The extraordinary growth of the electric lighting industry is familiar to all. Unfortunately the results of the special census of 1907 are not yet available, but the indications are that the five years which have elapsed since the previous census will show phenomenal growth. During these five years the gross sales of the great electric manufacturing companies have doubled, and the proportion of the output consisting of electric power apparatus and generating units of large size has greatly increased. An influential factor in the growth during this period has been the rapid development of long-distance hydroelectric power transmission plants.

Electric railways. Since the displacement of horse and cable cars in the cities a few years ago, electric railways have been extended to suburban and interurban districts and are rapidly forming a network over the entire thickly settled portions of the country. In the nature of their traffic, many of these roads are scarcely distinguishable from steam railroads, and many railroads are using them as feeders. In a few cases railroads have converted steam operated branches into electric lines.

Electrification of steam railroads. A beginning is being made in the electrification of our steam railroads. The New York Central, the Pennsylvania, the Long Island, the New York, New Haven & Hartford, the Grand Trunk, the Great Northern, the Erie, the Southern Pacific and others have electrified portions of their lines, and most of these are now in successful operation. Many of these roads are extending their electric zones. Thus far most of this work has been induced by terminal requirements, tunnels, heavy grades or other special conditions which emphasize the advantages to be derived from electric operation. The increase in capacity, convenience, and greater earning power as well as the economies resulting from electric operation will stimulate the electrification of steam railroads, just as these factors have stimulated the use of electric power in other industries. The problem presented is larger because of the necessity of interchangeability of equipment, and the development must necessarily be gradual on account of the magnitude of the interests and the large capital expenditures involved. The railroads are among the largest consumers of fuel, and electric operation, exclusive of the use of water powers, would reduce the coal consumption to less than one-half of that required for similar operation with steam locomotives.*

Tendency toward greater use of water powers. During the past few years, there has been renewed interest in water powers on account of the practicability of their use for the generation of power and the electrical transmission of this power to distant markets. The great hydroelectric development at Niagara was the first large enterprise of this character and has demonstrated its practicability. The census of 1905 gives a partial list of long-distance hydroelectric plants developing power aggregating 600,000 h.p. and this list can now be largely increased. Our most desirable water powers are being absorbed rapidly, and it becomes important, therefore, for us to take stock of our water resources and formulate plans for their control and proper utilization.

Inland waterways. In the improvements that have been made on navigable rivers, too little attention has been given to the development of the incidental water powers. On some waterways, as in several instances on the Mississippi, immense sums of money have been appropriated and expended on especially difficult portions of the river. If this money could have been made available in large amounts, instead of by driblets over periods of many years, water powers of great value could have been developed and the navigation effectively and permanently improved. Unfortunately this has not been our policy. Too often the appropriations have been inadequate for carrying out the work as it should be done, and frequently the work has not followed any well-digested plan.

With the data at hand, it is impossible to make an accurate estimate of the amount of power that can be developed incidentally to river navigation. A partial estimate of the power developed at existing government locks and dams places the amount at 1,600,000 h.p.† This is based on the mean low-water discharge for three months. This subject should receive careful consideration. Improvements in navigation should be made only after thorough study of the possibilities of power development. On the other hand, many water powers are on streams that are navigable, or are capable of canalization, and these streams should be developed for power purposes only after careful examination has been made of the possibilities of the stream forming a link in the system of inland waterways.

---

* "On the Substitution of the Electric Motor for the Steam Locomotive," by Lewis B. Stillwell and H. St. Clair Putnam, presented before the American Institute of Electrical Engineers, January, 1907.

† "Available Water Powers of United States Government Locks and Dams," collected by M. O. Leighton, United States Geological Survey.

Canalized rivers. There are many streams that are not now navigable, or are navigable for only a portion of the seasons, that can be canalized and converted into streams of great commercial value. The use of our waterways for both power development and navigation causes no conflict; these uses are in fact correlated and their interests harmonious. Where it is necessary to place a dam across a stream to develop power, the slack water so produced, with the addition of locks, renders otherwise impassable stretches of river available for navigation. Every water power development is vitally interested in obtaining a uniform flow of water. This exactly meets the requirements of navigation. The approximate realization of regularity of flow can be attained only by the construction of headwater regulating reservoirs and the preservation of our forests. Every water course that is improved for the production of power and for navigation produces, therefore, vigorous self-interested allies in the cause of forest preservation, headwater regulation, and the maintenance of conditions which are favorable to both interests.

Canals. Considerations which affect the use of our rivers and streams, as sources of power and for navigation, apply also to canals. Heretofore, canals built for transportation purposes have not been used, to any great extent, for the development of power. In some cases this has been on account of the limited supply of water, but more frequently it has been due to the great difficulty experienced by the animals in towing boats against the rapid current produced in the canal by the flow of water to the water wheels. In recent tests it has been demonstrated that canal boats can be towed by electric towing machines at a much lower operating cost than is possible with animals, and that operated in this manner the speed can be greatly increased.* The first cost of electric equipment is relatively large, but the change to electric towing will pay handsomely when the volume of traffic is sufficiently large. The traffic required is well within the ultimate capacity of the canal. With electric towing, the increase in the rate of current flow introduced by the development of water power on the canal is not a serious impediment to navigation.

---

* "Notes on Electric Haulage of Canal Boats," by Lewis B. Stillwell and H. St. Clair Putnam, presented before the American Institute of Electrical Engineers, March 1908.

Irrigation. There are large areas in the Western states where the soil is of wonderful fertility, but irrigation is essential to the successful growing of crops. The cultivated lands usually lie in valleys and water is carried to them through long and ofttimes wasteful irrigation ditches. In many cases the water could be utilized for developing power on the headwaters of the streams without injury to the irrigation interests, as is illustrated by the excellent work now being done by the Reclamation Service. The development of water power will introduce another party whose self-interest dictates the use of every available method of preserving the volume of water supply, its continuity, and regularity of flow.

In some cases irrigation channels can be converted into canals suitable for at least limited navigation, and where practicable this should be done. Some types of apparatus as now developed for towing canal boats by electricity require but little space along the side of the ditch and can be installed, usually, without additional grading wherever an irrigation ditch can be constructed. Electric towing cannot be economically practicable, however, unless the traffic reaches a considerable volume. With animal power the additional capital investment is small and is proportional to the amount of business handled. With electric towing the first cost is large and manifestly sufficient traffic must be secured to meet the capital charges before profits can be realized.

Water supply. What has been said upon the subject of irrigation canals applies to the development of the water supply for our cities. This work, like irrigation, should be carried out so as to develop the maximum water power possible without injury to the water supply.

The preservation of the purity of water for domestic use is of great importance to the welfare of the nation. A consideration of this subject, as well as of navigable water-ways, canals, irrigation and water powers, emphasizes the absolute necessity of competent supervision of the natural water resources of the country.

Regulation of stream flow. The flow of water in many streams annually fluctuates between wide limits. The low-water periods limit the profitable water power development and the high periods often cause disastrous floods. On most streams the average rate of flow for the year is many times the minimum flow. It is possible in some cases to utilize a flow approximating the average by constructing controlling reservoirs on the headwaters of the stream. Our Great Lakes form a natural reservoir of this character for the Niagara River. The Upper Mississippi has great natural reservoirs which assist in regulating its flow and which easily can be made very effective in its control. The notable floods of the Ohio River can be greatly reduced by the construction of controlling reservoirs on its headwaters which will result in the saving of millions of dollars now annually destroyed. On a stream which I recently investigated the minimum flow furnishes but 200 h.p. The construction of a storage reservoir increases the continuous 24 hr. power that can be utilized to 8000 horse power. If storage reservoirs could be constructed on the Susquehanna River, upon which a great water power development is now in course of construction, so as to obtain a uniform flow throughout the year, the available power at this site would be increased from a minimum of 30,000 h.p. to 200,000 h.p. While it is impracticable to construct reservoirs capable of holding back all flood waters, it is nevertheless certain that material gain would result from well-directed efforts along the lines suggested.

Auxiliary steam plants. On account of the great annual fluctuations now existing in stream flow, it has been found profitable to install steam plants supplementing the water power during seasons of low water. This method on account of its expense greatly handicaps the full development of our water powers and increases the amount that must be charged for the power. Under given conditions the most profitable amount of water power to develop and the best size of steam plant to install can be determined with great accuracy. The reserve steam station need not be located at the water power; in fact, it preferably should be located at or near the market for the power when that is distant, as greater reliability and continuity of power supply is thus secured. Headwater regulation would greatly reduce the necessity for such auxiliary steam plants.

Similarly the water power which can be purchased economically by a prospective customer who already has a steam plant in operation can be accurately determined. This amount depends upon the relative cost of generating different portions of the load by steam as compared with the amount charged for the water power supplied. In its economical application this method of operation works out so that the water power plant carries the steady portion of the load where the coal consumption per horse power capacity is greatest, and the steam plant is called upon to carry the peaks only where the coal consumption per horse power is least.

Interconnected plants. In addition to their reserve function in time of low water or flood, auxiliary steam plants and interconnected plants are valuable as insuring the continuity of power supply. If the lines are run overhead, as they must be for long-distance transmission in the present development of the art, all electric transmission plants are subject to occasional short interruptions due to storm, lightning, or malicious mischief. It is economical and desirable to tie together two or more plants, thus greatly increasing the reliability of service. If one plant or transmission line fails the others can be pushed to take the load. From an engineering standpoint, and from the standpoint of the customer as well as the power producer, this method of operation has great advantages.

Importance of power resources. In 1905 the value of the product of our manufactures amounted to $16,866,706,985; the total receipts of the steam railroads were $2,325,765,167.

In manufacturing the value of the product was $1,152 for each horse power installed and the yearly wages amounted to $248 per horse power.

In the railroad industry the gross receipts amounted to $555 and the yearly wages to $224 per horse power, rated on a basis comparable to that used in the census report covering manufactures.

I have selected these two classes of industry for the reason that they use the bulk of the power and illustrate its tremendous productiveness in increasing our wealth.

On the basis of the lower estimate of water power already mentioned, namely, 30,000,000 h.p., and applying the ratio which now exists between wages paid and power utilized in manufacturing and railroad industries, the development of this amount of water power implies an increase in wages paid amounting to about $15,000,000,000 per annum, an amount more than double the total value of our agricultural products at the present time.

Collection of data necessary. These figures emphasize the vast financial importance of our power resources and the necessity of their conservation and their intelligent development. Much can be accomplished by the national government in connection with irrigation of national lands and the improvement and preservation of navigable waters. The state governments can greatly assist in this work, within their respective territories.

Census of water resources. A reliable census of water resources is greatly needed. The Geological Survey has accomplished much in measuring and recording the flow of streams, but the work done is small as compared with that which remains to be done. Obviously, in order that records of this character shall constitute a uniform and safe basis for the very large capital investment which must be made in the future in order that our water power resources shall be properly utilized and our fuel supplies conserved, they should be made under the immediate direction of the national government.

Research work. The national government can render great assistance also in the research work which it has undertaken into the better utilization of our fuels. Excellent results have been obtained by the able body of engineers engaged on this work, but when we consider that we are now utilizing but five or ten per cent. of the heat value in fuels it is evident that much remains to be done.

Necessity of government regulation. Power and transportation are the two great physical bases upon which modern industrial development rests. Without power our methods of transportation must revert to a level with those existing in China. Up to the present time while nation and states have regulated and in some degree aided in the development in transportation, the power resources of the country have been utilized or wasted by the private individual and the corporation with little hindrance and still less regulation by the constituted authorities. Next to individual enterprise the most essential factor in the development of our national resources is wise governmental guidance, so applied as to insure the vigorous working of individual initiative and at the same time prevent the waste by individuals of that which is vital to our national welfare and to secure in the utilization of our natural resources the highest practicable degree of economy which scientific knowledge and engineering skill can attain.

DISCUSSION ON "THE ENGINEER'S ACTIVITY IN PUBLIC AFFAIRS —PUBLIC UTILITY COMMISSIONS AND FRANCHISE VALUATIONS", AT NEW YORK, APRIL 10, 1908

(Subject to final revision for the Transactions.)

George S. Coleman: In one respect I agree with Mr. Floy, engineers as a class are, perhaps, a little too modest; but I do not quite agree that engineers ought to be considered in any wise responsible for matters which are hard enough for other men to handle, men who are devoting all their time to it. I do think, however, that the time has come when groups of engineers, different kinds of engineers, should give the benefit of their concerted thought and action to any public question on which they are supposed to be especially well informed. In the case of a new bridge across any of our rivers, or a new subway, or a new elevated railroad, in fact any kind of engineering work likely to affect the public, this Institute, and every body of engineers who in any way might be related to that enterprise, should be heard officially. If Mr. Floy's suggestion this evening shall encourage among engineers the habit of not merely quiet, independent thought in their work, but concerted action after discussion, he will have accomplished a notable result.

I do not quite agree with Mr. Floy as to the constitution of public service commissions. In a country like this, where we are dealing, or called upon to deal, with a body brought into existence through the legislature, and representing the legislature as a sort of permanent committee, what is wanted is men who are intelligent, who are open-minded, who have had some experience in affairs, who are patient, who are thorough, who are industrious, and who have good judgment. Now, I would just as lief commit the affairs of the public service to a body of engineers as to any other body of men whose profession compels them to think, and whose training and experience tends to make them impartial. About three-fifths of the average legislative body are lawyers: that happens to be the present proportion on the public service commission for this district. It has been said that the difference between the common law and the statute law is that the common law is the perfection of reason and the statute law is made by the legislature; this is a legislative enactment and legislative enactments will have to be submitted to until a better law can be framed. But I do not agree with Mr. Floy as to the necessity of having experts as members of the commission. To follow that line consistently there would be needed as commissioners not only railroad men, gas and electrical experts, but expert accountants, expert financiers, experts on labor, and on every other subject that necessarily comes before the commission. Depend upon it, if there are three lawyers, or any number of lawyers on any commission, no agreement will be reached without discussion. With three engineers the same might be true, but I do not know from experience. I am willing to leave the composition of the commission to any body of intelligent men who have the necessary qualifications.

On the subject of what a commission should do, I must again differ from Mr. Floy. He cites with approval a quotation to the effect that where *operation* begins *regulation* should stop. If that were taken literally, after the commission has given an order to one of the transit companies to do certain things, like vestibuling cars, keeping cars in better condition, running more cars, or making more stops, regulation would be ineffective if it ceased where operation began. The commission for the first district employs a large body of competent engineers, the eyes, you might say, of the commission, a body of engineers of whom all engineers should be justly proud—men doing their duty well and faithfully, and without prejudice. These men report to the commission what they find and suggest what in their judgment would improve the operation of any public utility corporation. Their reports are submitted in condensed and accurate form, and if the commission may act of its own motion it will, after due consideration, act promptly. If any matter requires regulation, an order will be issued accordingly; if it does not, the matter will be dismissed. Although these things do not always appear in the newspapers, there are many improvements made by many public service commissions which are the direct result of suggestions of citizens or of the inspectors of the board of engineers connected with the commission itself. If the regulation is to be at all effective, details must be carefully considered.

As to the value of franchises, that is still an unsettled question. I sometimes think that the mechanism in the heads of the judges and lawyers and experts has stopped on a dead centre: it is going to require some little pushing one way or the other to bring to an end the question as to the proper way of valuing franchises. We have had some recent experiences in trying to value franchises for the purpose of taxation, and it is not an easy matter. Reputable men, will be found who differ honestly as to the proper way of valuing franchises. In three different cases, tried one after another, involving different points, a practically different result was reached in each instance. We have as yet no final decision by our courts. It does not follow because a corporation has invested many millions in plants which have been superseded or duplicated or thrown aside and new plants substituted, that it should earn necessarily a fair return on all its investments. Even the Supreme Court of the United States does not approve of that theory. There is a vast amount of what is known as "lost capital" that cannot be recovered. If Mr. Floy's proposition, with which I agree, is sound, that a corporation already in existence should be treated the same as a new corporation entering the same field, then, of course, as an inevitable result, all the capital expended and taken out has been lost, unless possibly it has produced a *good will*, which, with respect either to a gas company or to some railroad companies is almost a contradiction in terms. In this city, for instance, there is a railroad company having an excellent franchise. Originally, it was constructed as a horse railroad and operated as such for many years, and then turned into a cable road, and then, not long after, all the cable apparatus was removed and it was turned into an electric road. In 1900, when the Special Franchise Act came into effect here, there had been $26,000,000 represented by capital stock, $35,000,000 represented by bonds, and some floating indebtedness outstanding, and yet according to the appraisements made by the company itself, the total plant—tracks, roadbed, power house, and electrical apparatus, could be duplicated for about $10,000,000. There was a frightful waste, apparently and actually, of good money which never could be made up, unless that company should be treated differently from a new company starting with $10,000,000 capital and a similar franchise. Let us be thankful that we do not have to decide that question to-night.

The other suggestion in connection with the subject of the franchise was, that if a corporation should be restricted to earning what is called a fair return on its capital, and every corporation is treated on the same basis, improvements may be discouraged. But the modern theory seems to be that where there is state regulation a monopoly is not dangerous. It might well happen that one great gas company, one great electric company, one great transportation company, in the Borough of Manhattan, would be sufficient and would not be objectionable if it were wisely regulated. That would do away with one objection of Mr. Floy's resulting from competition, or lack of competition, if all corporations were to be treated alike.

A friend of mine, a lawyer, said to-day: " I sometimes wish very much that I could go out and deal with *things*, instead of with *ideas*." The more one deals with ideas, except as those ideas are related to practical things, the more at sea one becomes. I agree with Mr. Floy that engineers have been too modest, but in other respects I have to differ with him.

Chas. F. Lacombe: In discussing Mr. Floy's paper possibly more value will attach to these remarks if it is stated that my past experience has been largely in the line of building, operating and managing lighting and power plants, and that in entering the city's service it was entirely from a non-political standpoint, my work being purely of a professional character. During the last five years in the city's service a number of important discussions have come up, in which my particular work was involved, and, in consequence, I have been in close touch in these matters as they have occurred.

In discussing this paper, one may assume probably that public supervision of public utilities corporations by commissions or other bodies is necessary and has come to stay, not on the theory that all corporations are bad or that even a majority are bad, but on the theory as is shown by experience in late years, that wise and far-seeing regulation of public service is necessary to prevent the sacrifice of the service later on to the demands of that portion of the financial world which apparently requires great profits from stock speculation at the detriment of everything else. The present New York street railway situation is a shining example of this, as well as of a law as to transfers that is almost disastrous.

It has been said that the public gets no better service where there is public supervision, than it does where there is no supervision: that is a question that depends largely on the kind of control exercised. We will also need time to improve and perfect a method we have only just begun to use. This criticism may be true in a limited sense where the companies are working on a high plane, not only for the benefit of their stockholders, but for good service to the public. But the idea that there should be no public supervision because there are many of these companies, if carried to the limit, could be compared with the fact that we pass laws against crimes, not because the great majority are criminals, but to protect that majority against the very few who are.

It is also the duty of a public service commission to stand between the company and the public when the public demands are unfair or impossible. Some of the most difficult work the engineer has to do in public service is to prevent demands being made, mainly from ignorance, which are impossible to fulfil. It is our duty at times to protect the public against itself. This may sound odd, but a very good example is the present police traffic regulations.

From personal experience, I thoroughly approve Mr. Floy's contention that there should be some engineering representation on these commissions. Their work certainly comprises supervision of the most important engineering enterprises in the district which they control, and even one well equipped engineer of what we might call "general administrative engineering experience," would be a great aid to the commission in rendering unnecessary, if the term may be used, the conduction of the entire commission through matters of technique, which the engineer could settle at once, thus saving much time for the whole commission and giving them a clearer view of the main point at issue.

In reply to this, in discussing it with attorneys on a friendly basis, they are very apt to say: "Well, assuming the Board is made up with no engineering representation, they can hire engineers." The reverse of this proposition would be equally true, that if it were made up largely of engineers, it could hire representatives of other professions. In a way business men and other professions seem to regard the engineer in the light of an expert only, in a limited field, and that beyond this he has had little experience and has little knowledge of the affairs of the world at large with which they think they are more closely in touch. It is hardly necessary here to point out the large number of what might be termed "administrative" engineers, actively engaged in managing, at least in part, not only the engineering side but the business side of a great number of the enterprises.

The engineer advising a commission of non-engineers not being a member of the body, would certainly be compelled to exercise the greatest care and conservatism in expressing opinions, which might be misconstrued in discussion among men who were not engineers. Nor would such an engineer take the responsibility which he might take as a member of the commission. This fact, in my experience, has been noted a number of times. The salaries offered by the State for engineers serving the commission, but not members, would not attract the men that could be secured as commissioners by the honor and dignity of the position. A commission dealing largely with engineering subjects, therefore, made with a proper representation of lawyers, engineers, and business men, would I think be of more value than one in which either element was left out.

From lack of careful engineering consideration due to hurry and rush caused by public clamor, regulations have been passed by commissions and by the legislature itself, which could well be termed "inexpert legislation," and which the courts have rejected. This appears entirely unnecessary, and involves a waste of large sums of money. Much time and trouble would be saved in long and expensive lawsuits which have come from just this form of error. If an experienced, conservative engineer, with the power he would have as a member of such a commission, had been in touch with the matter he could probably have prevented a number of such cases in the past, for public clamor and government by newspapers would naturally not appeal to him as against his knowledge of the laws of nature. In support of this, I would call attention to an example of inexpert legislation, of which we have heard a good deal.

This is the suit of the Consolidated Gas Company against the attorney general, the district attorney, and the New York State Commission of Gas and so on, and also the City of New York, as contesting the constitutionality of Chapter 736 of the Laws of 1905, and Chapter 125 of the Laws of 1906, this latter law being known as "The 80-Cent Gas Act."

The Gas Commission set the price of gas to the private consumer at 80 cents in the city of New York, and the price of gas to the city for its own purposes, at 75 cents per 1000 cu. ft. A decision has now been rendered against the city by the United States Circuit Court, Southern District of New York, which will be appealed to the Supreme Court of the United States, for the settlement of certain points as to constitutionality. A great deal of pressure, as voiced by the newspapers, was brought to bear on the commission. If the commission had had an engineering representative of high standing it is probable that, taking into consideration the success of the sliding scale for gas companies in England, some such sliding scale would have been adopted here, instead of making a direct cut from $1.00 to 80 cents, and to 75 cents in the case of the city itself. This reduction might have been extended over a period of years, so that the increased consumption of gas, which seems inevitably to result from a decrease in price, would have convinced the companies that they would not be taking the risk of having to operate at a loss.

There is also in this law the requirement that gas shall be supplied at a pressure of not less than one inch, and not more than two and one-half inches in *any service main at any distance* from the place of manufacture. As a matter of fact, to-day modern gas appliances require really a higher pressure than the minimum set, and the city itself in requiring the operation of gas lamps is put in a peculiar position, in that it is forced to require a minimum pressure of one and one-half inches in order to operate the mantle lamps at reasonable efficiency, whereas the legislative act allows the company to fall to one inch pressure before the company is penalized. In Manhattan, with the very considerable rise in grade between the lowest point and the highest point, the rise in pressure due to the height of the column of gas, will alone force the gas pressure beyond the legal limits. The Consolidated Gas Company tried to operate within the legal limit, and they found that when they did they received a large number of complaints from people who could not operate their gas stoves and cook their meals on account of low pressure. The penalty for any violation of this condition was $1,000 for each offense. It has escaped my mind now as to how many times the companies were found above or below the pressure required, but the last time it was looked up, and that was a year ago, the penalties would have amounted to a very large sum.

The candle power of the gas was also raised from 20 to 22, which seems unnecessary, and if the gas fell below this candle power, the company was to be penalized by a fine of one thousand dollars for each offense. This also added materially to the cost of making gas.

Further than this, in the same law—Chapter 736 of the Laws of 1905—the companies were also penalized $1000 per offense in case they even sent a bill to the City of New York for over 75 cents per 1000 cu. ft. I cannot tell you the figure to which these fines would reach in case they had all been enforced rigidly and an attempt made to collect them.

The United States Circuit Court in its final order declares that all these penalites are unconstitutional and void and are not to be enforced. More than two years' very hard work were put in by both sides in this case, and the joint expenses of the city and the company will amount to a large sum. Meanwhile, the people of the city of New York have received little if any benefit. I think I can say safely that if it had been left to a board, having one or more competent gas engineers as members, these errors might have been avoided, and the price to the consumer gradually reduced.

In addition to these matters, caused by inexpert legislation, the Supreme Court of the United States has recently rendered a decision in what is known as "The Minnesota Case," in which they state that the laws as passed by the legislature in the State of Minnesota affecting railroads and warehouses, contain certain penalty clauses which would act to prevent the railroads and warehouses from going into court at all, and, in consequence, these penalites are unconstitutional and void. Beyond that they refer the matter back to some other court as to the propriety of the rates involved, in the following language:

> It cannot be to the real interest of any one to injure or cripple the resources of the railroads of the country, because the prosperity of both the railroads and the country is most intimately connected. The question of sufficiency of rates is important and controlling, being of a judicial nature it ought to be settled at the earliest moment by some court, and when a Federal Court first obtains jurisdiction, it ought, on general principles of jurisprudence, be permitted to finish the inquiry and make a conclusive judgment, to the exclusion of all other courts. This is all that is claimed, and this, we think, must be admitted.

It is apparent, therefore, that penalties which are not legal and reasonable will be considered very carefully by the courts in these matters. While the Consolidated Gas case does not show any clauses preventing the company from having its day in court, it does show penalties imposed on the disobedience of conditions which are impossible or unreasonable. One, if not two, of these conditions would have been condemned by engineers.

Decisions of this character certainly point out that legislation affecting public service corporations must be fair and reasonable, and should be made by men who know something of the engineering and operating conditions. They point out forcibly the necessity and propriety of having a skilled and experienced engineering member in a public service commission.

Mr. Floy also takes up the interesting question of franchises, what they are and what their valuation should be. To bring this matter up to date, I have procured and will read to you some definitions given of a franchise in the last decisions of the United States Circuit Court in the Consolidated Gas Case, as rendered by Judge Hough, and also as to the valuation of the Consolidated Gas Company's franchise.

It appears that, apparently, the question as to whether a public service corporation is entitled to add the value of its franchise to the tangible assets on which a fair return would be lawfully demanded, is to be submitted to the Supreme Court of the United States for the first time. The United States

Circuit Court points out that the investment of property in a manufacturing plant was made, not *in* the franchise, but *under* the franchise, and on the faith thereof. In speaking of the ways in which the value of a franchise can be stated, the court says, speaking probably of the usual methods of obtaining franchises:

> On every private sale of franchise property, the price paid is so much money lost to the public by official incompetence or worse, and such sale can confer on the vendee no right to compel the consumer to repay him a price which should have been paid to the State. For these reasons I believe that, on principle, the franchise should be held to have no value except that arising from its use as a shield to protect those investing their property upon the faith thereof, and that considered alone and apart from the property which it renders fruitful, it possesses no more economical value for the investor than does the actual shield possess practical value apart from the soldier who bears it.

The court then states that many decisions have been rendered, the trend of which is against his own views, but that for good reasons he must follow the weight of authority. He says:

> I conclude, therefore, that I am compelled to consider franchises not only as property, but as productive and inherently valuable property, and to add their value, if ascertainable, to the complainant's capital account before declaring the rate of return permitted complainant by the statute complained of.

In a later decision, after the re-opening of the case for certain reasons, speaking of his valuation of the franchise, the court says:

> It is not difficult to detect flaws in findings opposed to the settled opinions of the judge who happens to constitute the court.

The court in its first decision then goes on to the question of valuing franchises, and says that, for the purpose of condemnation or regulation:

> The value of the franchise depends wholly upon what is earned under it, and I believe the best way of finding out how much a franchise separately considered is worth, is to ascertain what those persons desirous of continuing operations under it consider it to be worth. In a corporation whose stock is freely bought and sold, such value is measured by the success attending the sale of stock based entirely upon capitalization of franchise, yet the value of stock issued only in consideration of the franchise is obviously dependent on earnings after the stock based on tangible property has received a satisfactory dividend.
>
> This is really the same measure of value that the New York Franchise Tax Commissions are using, except that instead of that reasonable return upon the tangible assets deemed by the commission as sufficient, there is substituted the opinion of the investing or speculative public as to what constitutes a satisfactory rate or return upon all stock. Thus, if the investment of a hundred thousand dollars in a franchise protected business authorized, in the opinion of the promoters, the issue of two hundred thousand dollars' worth of stock, and such stock for a number of years maintains itself at par, paying satisfactory dividends, it would be obviously fair to assert that in the opinion of the share-holders that franchise is worth one hundred thousand dollars, assuming no depreciation of tangible assets. Yet it will always be true that unless the whole net return, compared with the value of tangible property, is above a satisfactory return on the tangible investment alone, the addition of stock issued for franchise will be regarded as "water", and detract from the value of the entire issue, and I think this is conclusive proof that value in a franchise depends wholly on what the actual investment can earn.

> I consider the real reason which compels me to consider the value of franchises to be that for generations it has been the universal practice of American Corporations, supported by the opinions of courts and counsel to capitalize their franchises for all it was thought traffic or business would bear, until the country is full of share-holders whose certificates of stock are based upon the belief that in some way or other such certificates were legally created pieces of property and would, like other property be protected by Federal and State constitutions.

The court then goes on to value the franchise at this date on the basis of the valuation in 1884, when the Consolidated. Gas Company was started, proportioned to the value of personality and realty of thirty million dollars, the investment at that time in tangible assets. He finds the investment in tangible assets in 1905 is forty-seven million dollars, and the franchise valuation proportioned thereto would be twelve millions, which he allows. The court explains this in his later opinion, in which he states that the franchises of 1884:

> Might as well have been valued at twice the amount of stock then issued. It was nothing but an attempt to capitalize expected profits; but the attempt now has twenty years' success to justify it.

Further on he defines franchises as follows:

> The so-called franchises may be denominated " licenses, or tenancies at will " or " continuing trespasses ", yet what is being done under them is a fact, a profitable thing, a taxable property by the law of this state, The State of New York, therefore, is estopped from continuing to tax that property by one set of representatives and denying it all value through the instrumentality of another.

The contention of the city of New York in this matter was that the franchise had value as regards condemnation or sale, but that it should not have value when it capitalized that value and charged a return upon it against the public that gave them the franchise.

It will be very interesting to note the decision when it is given by the Supreme Court of the United States, and it is to be hoped that it will go into the question of what is the proper way to value a franchise, particularly when, as stated, this has come before the court practically for the first time, strange as that may appear.

I trust that I have not quoted too much law, but I thought that it would be of service to bring in some of the decisions which have been rendered since Mr. Floy wrote his paper, and I also thought that it might be of value to a number of engineers who are at times confronted with similar problems.

H. M. Brinckerhoff: This question of the necessity of co-operation between corporation officials and the public service commission was made a prominent part of the speech of Commissioner James E. Sague, of the Second District of the State of New York, at the annual banquet of the Stevens Alumni Association. He said:

> Satisfactory results can only be obtained by cordial co-operation between the corporation officers and the commissioners in the same spirit which was exercised in the conference between the Interstate Commerce

> Commission and the corporation accountants in the preparation of the uniform system of railway accounts recently adopted. . . .
>
> In all departments of the commission's work the same necessity for co-operation is apparent. We all need to be educated in this field. We can probably learn much from Europe, and especially from England, where the Board of Trade has functions similar to those of our commissions. The commissions need all of the intelligent advice that they can get, and all criticisms if kindly made, will be received in an humble spirit. We want to know where to begin in our work. We want to learn what is most important to be done now, and what ought to be left for the future, and we need especially perhaps to learn where to stop.

This is the carefully considered, positive statement of the only technical member of the New York State Public Service Commission, and when it is considered that Mr. Sague has had long experience in railroad operation as well as large corporation affairs, it forms a very striking argument for exactly the idea we are advocating.

Our public utility boards and railroad commissions to attain full usefulness should have upon them some experienced men, men who have been through the mill and who will not ask the impossible. No man, no matter how sincere and devoted, can grasp in a few minutes, operating questions with which he has never had actual personal experience.

The great variety and complexity of questions coming before public regulating boards require for proper balance a membership representing legal, financial, and commercial experience, but equally important is it that some experienced operating members should sit upon these boards in order that a proper appreciation of the effect of proposed orders and regulations may be considered and clearly appreciated by the board during its deliberations.

At this point I part company with the author in that I do not agree with his contention that commissioners should be primarily and exclusively engineers, and I doubt whether this was in the mind of Mr. Perkins when he made the remark:

> A Railroad Commission should be composed of railroad men who can deal with the questions arising in a practical way.

The questions which come before boards of public control are 90 per cent. operating questions in the sense that they affect directly or indirectly the methods of, quality of, or remuneration for, operation. I have no fear that legislation or the rulings of utility boards will reverse the laws of gravity, strength of materials, or even the design of rail-sections; but I do fear that their action in certain instances will have an unexpected detrimental effect upon the very service which they were hoping to improve, a result which experienced operating men would clearly foresee.

Purely engineering questions should be handled by engineering experts who are making a specialty of the particular line momentarily under consideration. Mr. Floy's remark in regard to hired experts seems to be a condemnation of all consulting engineering work, as there should be no difference in the amount of responsibility assumed or service rendered when acting for a public commission, a corporation, or a private individual. No one engineer-member of a commission could expect to keep up with the vast intricacies of all the engineering questions which might come before the board, whereas a practical, experienced operating man who had had the daily, monthly, and yearly running of a plant or system under his charge, would have sufficiently good judgment and experience in engineering matters to know when he must call upon an expert engineer and properly to select such an expert.

There can be no question that in many instances where public service commissions make rulings adverse to the company, which afterwards prove unwise, it is quite as much the fault of the company as of the commission, the company not having fully laid before the commission the actual facts in the case. In this connection the attitude taken necessarily, or perhaps we might say customarily, of presenting matters to a commission in public meeting as they would be presented before a criminal court, brings about an unfortunate result.

It is probably impracticable at the present time to expect matters of this kind to be considered openly in a fair, candid discussion, but if such a course could be pursued I am satisfied much better results would be obtained than by the formal, legal methods now pursued. Our commissions would very seldom go radically wrong if they had the real facts placed clearly before them. Two conflicting, cleverly concocted, partisan statements, on the contrary, befog rather than clarify the issue.

Every operating man knows that to make the worst appear the better reason, while it may be a triumph of legal skill, is not a satisfactory method of deciding operating questions. There may be differences of judgment, but an accurate basis of facts is necessary for the protection of both parties to a controversy. A short cut to a correct result would in many cases often be made by the presence on the board, as has been suggested, of experienced operating men, and I am greatly in hopes that we will see before long the appointive power fearlessly used to place upon these commissions carefully selected men of this class to co-operate with and assist the otherwise excellent personnel of which the commissions are composed. Such appointments would not only be just to the railroads but beneficial in the long-run to the public.

Louis A. Ferguson: I heartily concur with Mr. Floy's views as to the desirability of having thoroughly trained and well equipped men of technical knowledge and broad experience upon the various commissions entrusted with the duty of regulating rates or the conduct of business by public utility corporations. It appears to be the trend of modern legislation to take from the various legislative bodies, city councils, etc., the power of regulation of public service corporations, and place it in the hands of commissions. This is extremely desirable, not only from the viewpoint of the corporations, but of the public as well. Attempted regulation of public utility corporations by large, unwieldy governing bodies such as the board of aldermen of large cities like New York, Chicago, Philadelphia, or Boston, is seldom satisfactory either to the corporation or the public. Such bodies rarely number among their members men of sufficient technical knowledge and training to enable them to pass upon the questions involved with any degree of satisfaction. For instance, when the regulation of the rates to be charged by a telephone company, a gas company, or an electric lighting company comes before a body of men numbering from fifty to seventy, it is almost impossible sufficiently to educate so great a number of men in any reasonable period of time so as to enable them to pass intelligently upon the questions involved. Usually many months, and often years, are spent in hearings before such bodies, and finally a rate is established which is not infrequently but a compromise between the rates proposed by corporation and the board of aldermen; it is not a rate based upon a thorough, scientific basis of reasoning. During all this time the affairs of the corporation are in a disturbed condition, its directors cannot plan any extension of business, the proper financing is made much more difficult, and stockholders become alarmed at the various reports as to the probable action in regard to the fixing of rates. How much more satisfactory and how much fairer is a hearing for such a purpose when conducted before a properly equipped commission appointed either by a legislature or by a governor, a commission numbering say three, five, or seven, all of whom, or at least a majority of whom, are thoroughly trained engineers, possessed of a scientific knowledge of the subject under discussion, and able, of their own knowledge, to arrive at an absolutely fair result, fair both to the corporation and to the public.

Practically everyone will concede that a public utility corporation is entitled to a fair return upon its investment. The chief difficulty encountered is the varying views of different people as to what is meant by " fair return ". Some extremists contend that the legal rate of interest fixed in any state is a fair return for public service corporations doing business in that state, while others contend for as high a rate of interest as capital can secure by engaging in any mercantile or other legitimate enterprise. In my opinion neither of these views is correct. There are but few capitalists that would care to engage in any industrial enterprise, such as manufacturing, where the returns upon the investment would be less than twelve per cent. A review of the returns made upon capital invested in banking enterprises throughout the country shows a very high return of interest upon the capital invested, in many cases running as high as twenty, thirty, fifty, and in one case at least as high as one hundred and twenty per cent. No one will seriously contend that a public service corporation is entitled to so high a return upon its investment as is referred to in the case of banks; nor, on the other hand, should anyone seriously contend that such a corporation is entitled to, say, only five per cent. return upon its investment, five per cent. being the legal rate of interest in the State of Illinois. It is axiomatic that the return upon capital invested in public service corporations should be sufficient to entice capital. There is no magic about a public service corporation or about the business in which such corporations engage which will serve to attract and interest capital, unless the return upon the money invested be approximately that which might be earned upon the money if invested in other legitimate enterprises. It is my opinion that public service corporations would be and should be satisfied with a lower rate of interest upon their investment where their rates and other business dealings with the community are controlled by a commission, small in number and composed of, say, trained engineers, than they would deem satisfactory if their rates and other business dealings were controlled, as they are now, by state legislatures or boards of aldermen. In the first case the corporations may be reasonably sure that no radical measures will be advocated by a commission which would serve to throw unnecessary burdens upon the corporation, or which would prevent the corporation from earning a fair return upon its investment. In the second case the corporation is compelled to exist in a constant state of uncertainty, never knowing what wave of radicalism may strike the community and be reflected in its lawmaking body, whereby public clamor may result in the fixing of rates so low as practically to amount to confiscation, or in the surrounding of the business with such so-called safeguards or other provisions relating to methods of bookkeeping, etc., as to make it; if not extremely difficult, at least extremely expensive to operate its business in a satisfactory way and in compliance with the law.

Too much stress cannot be laid, however, upon the absolute necessity of appointing as members of state commissions entrusted with the regulation of the affairs of public service corporations, men of undoubted integrity, the highest order of ability, and possessing the confidence of the community. In fact, the members of such a commission should be the same class of men, so far as their standing and ability are concerned, as we expect to find in the Supreme Court of the United States. If these commissions are to be made fat berths for politicians, public service corporations have only jumped from the frying-pan into the fire. The temptations and possibilities for wrongdoing in such a position are enormous, and weak or unscrupulous men occupying such positions would have it in their power either greatly to oppress the corporation or so greatly to favor it as to create much dissatisfaction in the community, a state of affairs which would eventually result disastrously to the corporation.

There is no doubt that the sentiment of the public is now undergoing a marked change in its views toward public service corporations. We have passed through an era of radicalism during which the public regarded large public service corporations in the light of public enemies, and believed that no measures were too severe to be directed against the corporation and no restrictions too rigid to be thrown around them. It was formerly thought that competition was the thing, and that by granting a license to several gas companies, several electric lighting companies, or several telephone companies, much better service and much lower rates might be secured. It has been discovered that this theory is entirely wrong, and it is now rapidly becoming the sentiment of the public that the best interest of the public is served by a properly regulated monopoly. It has been discovered that whenever two or more public service corporations engaged in the same line of business are serving the same community, they are not likely to remain separate very long. Duplication of plants is a waste of capital which is not economic, and, if persisted in, necessitates a much greater outlay for cost of operation. If there is *bona fide* competition between two such corporations, it means a war of annihilation until the weaker of the companies is forced out of the field. This militates against good service and also prevents conservative capitalists from investing money in public service corporations doing business in a community where such a state of affairs exists. Where a public service corporation may be assured of a monopoly, or a practical monopoly, of the field it may very well consent to do business at a much lower rate of interest upon its investment, because the fear of irresponsible competition is removed and the business may be conducted with an exact knowledge of all the factors entering into the cost of conducting and maintaining the corporation and prosecuting its business.

The remarks of Mr. Floy upon the desirability of engineering experts equipping themselves for service upon state commissions and the advisability of the various institutes and similar bodies of engineers taking an interest in public affairs with a view to having their members placed upon such commissions, commends itself to me, and I am a firm believer in the advisability of such a policy on the part of our engineering bodies.

Henry L. Doherty: There is so much to be said both for and against public control of public service corporations that nothing short of a large volume would cover all of the important things which might be considered. Therefore, I shall touch briefly on only one or two points of first importance.

Public opinion is such that perhaps public control of public service corporations is inevitable. It would seem self-evident that the scope of this control should be the least possible to insure protection to the public. The recent tendency of some of the public utility bills, however, seems to anticipate public general managership rather than public control.

The broader the scope of control attempted the less efficient will be the work of public control, and an attempt at too much breadth will defeat the whole scheme of public control. If public control is inevitable, this control must be shaped so as to make its disadvantages the least burdensome and its advantages the most beneficial. To insure impartial decisions the executors charged with public control should be as far removed as possible from the influence of public opinion.

Public control, however, is apt to convince the owners and managers of a quasi-public corporation that only the minimum returns may be earned and distributed. And this interpretation of public control removes all incentive on the part of the owners and operators of quasi-public corporations to make proper effort for economies and improvements. The so-called "London Sliding Scale"—which is a very incomprehensive name to a very comprehensive subject—is an attempt at a reasonable division between the public and the owners of the property for improved results. For public control to be a success it must be automatic as far as possible, and the company must be premiumized in the shape of higher returns for improved results. The plan for the accomplishment of this end can, I believe, be best secured by, and demands, engineering consideration.

The men charged with this work must have an extraordinary degree of intelligence, or else a combination of experience in the business which they are expected to control coupled with a high degree of intelligence.

These executors are generally constituted as commissions, and they in turn must have a competent staff of accountants, statisticians, and experts. The success of the plan must rest primarily with the fairness and intelligence, not only of the commission itself, but of all their various assistants. Under modern conditions a public service commission cannot do either intelligent or effective work without competent engineering advice or assistance. This I think is generally recognized, and the commissions accordingly have their engineering staffs. But in selecting the commissioners themselves the engineering profession should not be overlooked as a very likely source of the best available timber.

W. W. Freeman: With respect to the question as to what would be the best make-up of the public service commission, I have no suggestions to offer. I have found no difficulty in agreeing with some things that have been said by each of the speakers. As one who does not claim to be an engineer, I entertain no fear whatever from the standpoint of having the engineers represented on the commission. At the same time, I should be equally anxious to have a thorough representation of broad gauge business men who would view the situations presented from the executive and business standpoint, entirely aside from engineering or technical ideas.

I agree with Mr. Floy that the matter of determining the value of a franchise is likely to adjust itself when it has been definitively decided that the valuation admitted for the purpose of taxation is equally available as an asset upon which a fair return can be earned.

In the matter of a fair return, Mr. Floy apparently thinks that six per cent. is admitted from the legal standpoint, that nine per cent. or more is asked for by the investing public, and that eight per cent. would probably be acceptable, and that the franchise should be fixed at a valuation that will make up the difference. If the franchise has a legal valuation the companies are entitled to the return on that valuation, whether it be for property that is intangible or tangible, and it would seem that if we are claiming eight per cent. or any higher per cent., we must of necessity in justice to our own interests ask and demand that return upon the fixed valuation of the franchise the same as on the tangible property.

It seems to me that the plan of fixing the gross income which a company shall be entitled to earn, after its expenses, plus depreciation and plus six per cent. of eight per cent. return, leaves altogether out of consideration the fundamentals on which the business is based. The first consideration in public service regulation doubtless ought to be a demand for good service. I think we will all agree with that. Then of course comes the demand for a reasonable charge, which is admitted, and then the question of a fair distribution to the stockholders, which is also admitted. But equally important with these three is what amount over these items must of necessity be assured to the company for permanent and successful operation. There are years when the revenue will be less than in other years, and any company that disburses all of its earnings in its good years will have no earnings to disburse in the poor years. The maintenance of a permanent investment requires of necessity some reserve, and in addition there are the expenditures attaching to extension work and improvements. These vary with the company, and the idea of the company earning only the amount which it needs for distribution to its stockholders seems to me to be ill considered. I believe that public control should be exercised over, not so much what the company earns but the amount disbursed, and what it does with the balance. For instance, a company that has a capitalization of $1,000,000 and earns and distributes, say, over and above expenses, eight per cent. on $1,000,000, distributes $80,000 a year, and that company requires $50,000 or $100,000 a year for the extension of its business in new work. Now, whether that company issues additional capital during each year to take care of these extensions, and pays the same rate of dividends upon the total capitalization, or whether it earns a sufficient amount to enable it to pay a fair rate of return to its stockholders, and also a sum beyond that which will enable it to take care of its extensions and additional capital, is the same thing to the public, but it means a great deal of difference to the company. I feel that it would be very much more conservative management, very much more in the interest of the corporation and public if the company should be able to manage its business so that it could take care of reasonable expansion independent of its ability to raise further capital from year to year, so long as it is supervised in respect to its charges and its disbursements, and what it does with the surplus. If that plan were followed, it would be very much in the public interest as well as in the interest of the company.

George S. Coleman (by letter): I should like to add a comment on that part of Mr. Floy's paper in which he says:

> A perusal of the minutes of the hearings held before state commissions will convince any unprejudiced person that a disproportionately large amount of evidence and testimony is submitted, in the consequent unnecessary financial expense and consumption of time for the purpose of explaining terms, apparatus, and methods of operation and expenditure to commissioners who, in general, should be acquainted with the matters being considered.

In justice to commissioners generally it should, perhaps, be said that their official duties require them not only to decide questions but to preserve a record of the testimony submitted, and to make the record intelligible to those who are not experts. In an ordinary suit at law technical terms have to be explained for the benefit of court and jury. The commissioners must fortify their findings by a proper record, so that if their decisions are challenged they may properly defend them. While this involves tedious inquiry it seems almost essential to orderly procedure.

Henry Floy (by letter): It is a pleasant surprise to find so much agreement among the engineers, if not among the lawyers, with the views expressed in my paper. Even Mr. Coleman agrees with my opinions more fully than perhaps he seems to admit, when he says:

> I would just as lief commit the affairs of the public service to a body of engineers as to any other body of men whose profession compels them to think, and whose training and experience tend to make them impartial.

I do not for a moment wish to convey the idea that various engineering specialists, experts in particular departments, should make up a commission. I do not argue that an electrical expert, a specialist, should properly be a member of the commission, or as Mr. Brinckerhoff seems to understand, that "commissioners should be primarily and *exclusively* engineers." I would consider a mechanical engineer, if he knows something of electrical work, hydraulic work, gas work, and has had experience in the operating and commercial departments of a public utility corporation, much better qualified to make a good commissioner. The same way with the railroad man. What is wanted is not an expert designer of cars or locomotives, but an engineer experienced in railroad organization and operation. Mr. Coleman makes the too common mistake, which I referred to, of considering a man with a technical training capable of passing on technical questions only, whereas such training is, frequently, merely the basis for success in commercial and economic affairs. I do not argue that a commission should be made up, entirely, even of widely experienced engineers; that would be as erroneous as constituting it of lawyers or business men. Neither can I see any necessity for three out of five members of a commission being lawyers; for a large amount of the work of a commission has nothing to do with law, as such, while much of it has to do with engineering questions. From my experience before commissions, I believe more helpful and practical results would often be accomplished in a simple and expeditious way by following procedure which might possibly be termed engineering rather than legal. Why questions involving matters of an engineering nature cannot be best answered by a commission constituted partly of men who are conversant with engineering affairs, I cannot understand. My plea is for a balanced commission consisting of engineers, business men, and lawyers.

With regard to operation versus regulation, Mr. Doherty's discussion very completely expresses my view.

Mr. Brinckerhoff's ideas and my own, as to the value and propriety of retaining consulting engineers, are, I believe, identical. My thought was that the responsibility for a decision must rest upon the commissioners; it should not on any plea be shifted by them to " hired experts ", however competent, either as consultants or direct employees.

As I understand Mr. Freeman, it does not seem to me he quite appreciates some of the points I have tried to bring out. There is no getting away from the fact that commissions are being appointed and franchised valuations are being determined. One need not agree that one-third is the correct valuation of a franchise, but some valuation must be fixed and it seems to me we want to study this question and try to determine the figure that will be reasonable and fair to both sides. Purely as an illustration, I have suggested a franchise valuation of one-third and a rate of six per cent. because in some cases that is a fair valuation and rate, and we may be able in some instances to get the opposing sides to compromise on these figures. Of course, as an Institute we do not want to stand committed to six per cent. or any other per cent., but as a practical proposition it is comparatively easy to get money to invest at eight per cent. if the investing public is assured that it will be protected in an eight per cent. net return. In the past the New York public service corporations may not have been able to get investors interested on an eight per cent. basis, but they will be able to do so in the future if their interests are protected by a commission.

I agree with Mr. Freeman as to the necessity of a reserve account, which, however, together with other similar items, was covered, in my thought, by the percentages allowed for " maintenance " and " depreciation." The amount and itemizing of these several details is, of course, immaterial for the purpose of here illustrating a method of determining franchise valuation. I differ with Mr. Freeman as to his suggestion that a public service corporation should provide for its expansions from earnings; I had supposed it was now pretty generally agreed that extensions should be charged against the capital account instead of being made a part of the charges for service.

*A paper presented at a meeting of the Pittsburgh
Section of the American Institute of Electrical
Engineers, Pittsburgh, Pa., October 2, 1907*

Copyright, 1908, by A.I.E.E.

(*Subject to final revision for the Transactions.*)

METHODS FOR LOCATING TRANSPOSITIONS OF WIRES AND SPLIT PAIRS IN TELEPHONE AND TELEGRAPH CABLES

BY HENRY W. FISHER

Some of the telegraph companies demand that there shall be no transpositions of wires in any of the layers in a telegraph cable. By this is meant that the wires of every layer must have the same relative order at each end of the cable. There is usually a tracer or wire covered with different colored paper from the rest in every layer, and by counting from this tracer any particular wire can be located at any point in the cable. If a wire is fifth from the tracer in a clockwise direction at one end of the cable, it will be fifth from the tracer in a counter clockwise direction at the other end of the cable. By this general plan it becomes possible to identify wires without resorting to some of the common methods of testing. However, in order to be able to place implicit reliance in a scheme of identification of this sort, not only must the cables be manufactured correctly but the jointing must be made by skilled men who are careful to connect the wires of each layer in consecutive order, and as an extra precaution make repeated tests at both ends of the jointed sections as the work of splicing progresses. Even after exercising the greatest care, a transposition may occur. The object of the present article is to show how a fault of this kind can readily be located by some methods devised by the author.

To do this a ballistic galvanometer, battery, condenser, and discharge key can be employed, but the writer prefers to use an alternating current or continually reversed direct current, a wheatstone bridge or its equivalent, a condenser, and, as a current detector, a telephone, or, still better, a vibration galvanometer.

Instruments are now made which are suitable for this work, provided that the length of cable is great enough to obtain sufficiently discriminating values between the various tests made.

As the methods employed deal entirely with measurements of electrostatic capacity, which are ably described in many text and hand books, the writer will here only briefly show by diagram and description the arrangement of sensitive apparatus which was employed to verify the accuracy of the methods used.

Fig. 1 gives in diagrammatic form the connections and apparatus employed. R, R' and R'' are non-inductive resistances wound

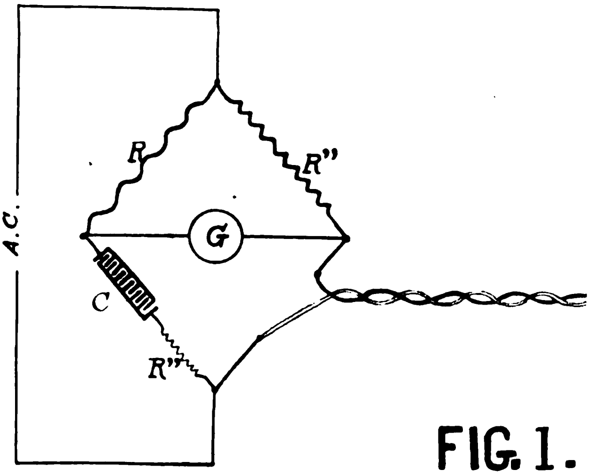


FIG. 1.

also so as to have a minimum capacity. G is the vibration galvanometer, C a standard condenser, and $A\ C$ the alternating-current source which, by means of an electrically driven tuning-fork arrangement, was kept at a frequency that gave maximum vibration to the galvanometer needle. The resistance R'' is needed to obtain the condition of balance or zero vibration of the galvanometer.

The plan of operation was to keep R' constant and vary R and R'' until the galvanometer ceased to vibrate. R'' does not enter into the calculation of capacity which is represented by the formula $\frac{R}{R'}\ C$. Therefore, as R' and C were constant, the relative capacities are proportioned to R, and as we deal here entirely with relative values the figures given for the different tests are the R resistances required to give zero vibration to the galvanometer.

Telegraph cables. Before proceeding to the derivation of formulas, it is important to remember that the theory of relative capacities with different connections in bunched or paired telegraph or telephone cables is extremely complex. The formulas here given are not absolutely correct, on account of certain very small capacity effects that are ignored for the sake of simplicity. They are probably close enough, however, because it is impossible to make cables of this sort and not have in the capacities of different wires variations of as much as five or ten per cent., which would be sufficient to cause great discrepancies, even if theoretically correct formulas were employed.

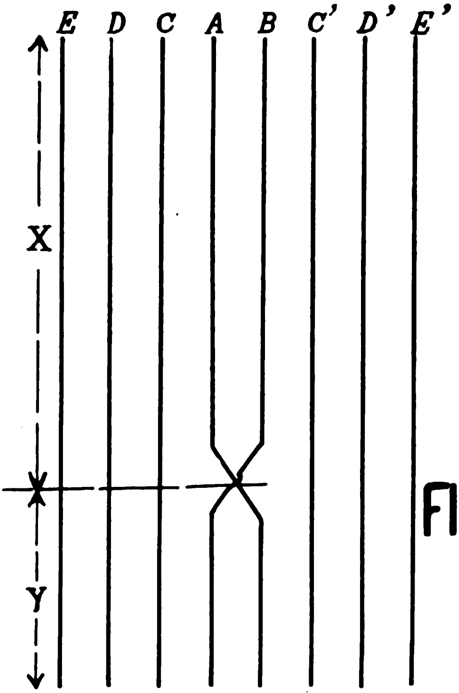


FIG. 2.

We shall first consider the simplest case; namely, that where adjacent wires in a telegraph cable are transposed, and after that we shall give general directions which are applicable to almost any condition of single transposition.

Fig. 2 represents a number of wires in a layer of cable. A

and B are the two wires which are transposed at a distance of X feet from the end where the test is applied and Y feet from the other end of the cable. In representing a test between two wires the letters designating each will be coupled together thus: The capacity between A and B will be spoken of as capacity $A\ B$.

The general plan of procedure is to determine the capacity between adjacent wires and also the capacity between wires C and E, the latter being selected so that the number of wires between C and E is equal to the number between C and B or between C' and A.

If the capacities between C and A, and between C and B, are then measured we can derive a formula which will give the approximate distance to the fault. In order to get good average results it is advisable to make a number of measurements of similarly placed wires as is shown below. The first thing to do is to determine the relative capacity values of the following combinations of wires—$A\ B$, $C\ E$, $C'\ E'$, $C\ A$, $C'\ B$, $C\ B$, $C'\ A$.

$$\text{Let capacity } A\ B = a \tag{1}$$

$$\text{" \quad "} \quad \frac{C\ E+C'\ E'}{2} = b \tag{2}$$

$$\text{" \quad "} \quad \frac{C\ A+C'\ B}{2} = c \tag{3}$$

$$\text{" \quad "} \quad \frac{C\ B+C'\ A}{2} = d \tag{4}$$

Let L = the total length of the cable.

$$\text{The capacity per foot of (1)} = \frac{a}{L} \tag{5}$$

$$\text{" \quad " \quad " \quad " \quad " (2)} = \frac{b}{L} \tag{6}$$

From which we get,

$$\frac{a}{L}x + \frac{b}{L}y = c \tag{7}$$

$$\frac{a}{L}y + \frac{b}{L}x = d \tag{8}$$

Solving equations (7) and (8) for x we have,

$$x = \text{the distance to the fault} = \frac{a\,c-b\,d}{(a-b)\ (a+b)} \times L \tag{9}$$

Now as $x + y = L$, we can substitute $y = L - x$ in equations (7) and (8) and get the following results,—

$$x = \frac{c-b}{a-b} \times L \qquad (10) \quad \text{from equation (7)}$$

$$x = \frac{a-d}{a-b} \times L \qquad (11) \quad \text{from equation (8)}$$

Equation (9) is the proper one to use because equations (10) and (11) do not generally give concordant distances, although their average is usually near the distance obtained by equation (9).

To give the above formulas a practical test, two wires were transposed at 130 ft. from the end of a cable measuring 280 ft. and the following values were obtained.

TRANSPOSITION NO. 1.

$$a = 167$$

$$b = \frac{132.5 + 133}{2} = 132.75$$

$$c = \frac{148 + 145.5}{2} = 146.75$$

$$d = \frac{147.5 + 150.5}{2} = 149$$

Substituting these values in equation (9) we get,

$x = 128.9$ ft., or about 1 foot from the transposition.

Substituting in equations (10) and (11), the values of x are 113.6 ft. and 146.1 ft., or an average distance of 129.8 ft.

TRANSPOSITION NO. 2.

$$a = 161.5$$

$$b = \frac{127 + 130}{2} = 128.5$$

$$c = \frac{138.5 + 141.5}{2} = 140$$

$$d = \frac{140.5 + 142.5}{2} = 141.5$$

Substituting these values in equation (9) we get,

x = 129.6 ft., or about 0.5 ft. from the transposition.

Substituting in equations (10) and (11) the values of x are 96.9 ft. and 168.4 ft., or an average distance of 132.6 ft.

As mentioned before, it will be noted here that the values found by equations (10) and (11) differ widely. This may be partly due to inequalities in manufacture, but is more likely caused by the formulas being only approximate. The average value of (a) as measured should be slightly too high, and this would make the results by formula (11) too great. In formulas (10) and (11) nearly equal terms are subtracted and this is always a source of error. This kind of test is necessarily of such nature that even slight irregularities in manufacture may cause great differences in the calculated distances. It is for this reason that so many measurements have to be taken, for we are enabled thereby to obtain average results.

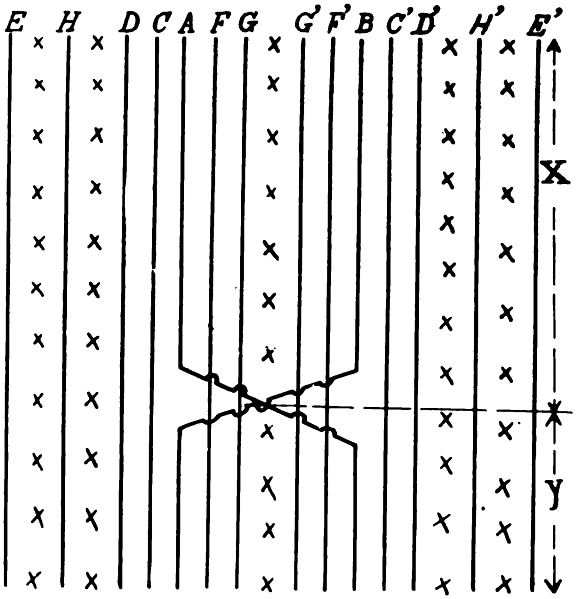


FIG. 3.

We will next consider the case where there are several wires between the transposed wires, which, as before, should be marked A and B. The wire adjacent to B should be marked C' and that next to A should be marked C, as indicated in Fig. 3.

Then select and mark a wire E such that the number of wires between C and B is equal to that between C and E. Also select and mark a wire E' such that the number of wires between C' and A is equal to that between C' and E'.

The tests can now be made exactly as described above, with the exception that for capacity $A\,B = a$, the capacity between several pairs of adjacent wires near but not including A or B should be determined and the average of these taken as (a) in formula (9). The wires generally measured are $C\,D$, $F\,G$, $F'\,G'$, $C'\,D'$. After the values of (b), (c), and (d) are found, the distance to the fault can be calculated by equation (9), and, if desired for the sake of comparison, by equations (10) and (11).

A separate set of values for b, c, and d can be found by selecting the wire H so that the number of wires between F and H equals the number between F and B; also the wire H', so that the number of wires between F' and H' equals the number between F' and A.

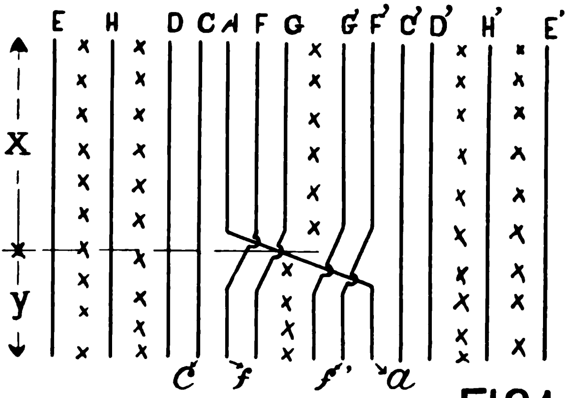


FIG. 4.

Then

$$b = \frac{F\,H + F'\,H'}{2} \quad c = \frac{F\,A' + F'\,B}{2} \quad \text{and } d = \frac{F\,B + F'\,A}{2}$$

With these and the previously determined value of (a) a check value of x can be found by equation (9).

Fig. 4 illustrates the case of a single displaced wire A. Here the number of wires between C and E and between C' and E' equals the number between C and a. Also the number of wires between F and H and between F' and H' equals the number

TABLE I.

Relative Capacities = *R* in Fig. 1.

Test between wires	Fault No. 1		Fault No. 2		Fault No. 3		Fault No. 4		Fault No. 5		Fault No. 6	
	m	*n*	*m*	*n*	*m*	*n*	*m*	*n*	*m*	*n*	*m*	*n*
C D	412	416.5	421	426.7		384	375	383	356	363	355.5	362.5
F G	419	427.5	419	422.5		380	379	383	368.5	376	367.5	375.5
F′ G′	410	419				373.5			377	386	375.5	385.5
C′ D′	403	412.5	420	427		381	382	385	376	378	372.5	377.5
Average = *a*	411.3	419	420	425.4		379.6	378.7	383.7	369.4	375.8	367.8	375.4
C E	344.5	358.5	343	357.5		324	313	324.5	304	313.5		
C′ E′	342	359	344	359.5		328	307	320.5	301	314		
Average = *b*	343.2	358.8	343.5	358.5		326	310	322.5	302.5	313.8		
C A	357	373	354.5	369		360	371	380.5				
C′ B	353.5	369.5	362.5	377		357.5	365	377.5				
Average = *c*	355.2	371.2	358.5	373		358.8	368	379	319.5	329.5		
C B	405	413.5	402	411		353	327.5	345.5				
C′ A	398	407.3	401.5	411		353	325.5	341.5				
Average = *d*	401.5	410.8	401.8	411		353	326.5	343.5	361	369.5		
F H	348.5	361.5	354	363.5		325	318	328			297.5	313.0
F′ H	335.5	352.5	354	365		330	316.5	327.5			302.5	315.5
Average = *b*	342	357	354	364.3		327.5	317.3	327.8			300	314.3
F A	370	376	369	375		363	368	374.5				
F′ B	356	369	366	373		355	373	380				
Average = *c*	363	372.5	367.5	374		359	370.5	377.3			323.5	337
F B	408.5	417.5	407.5	414.5		354.5	334	340.5				
F′ A	399	406.5	398	404.5		350	338.5	347				
Average = *d*	403.7	412	402.8	409.5		352.3	336.3	343.8			365.5	374

m indicates that other wires in cable were free and not grounded.
n indicates that other wires in cable were all grounded.

between *f* and *a*. Having tagged the wires as just described and as illustrated in Fig. 4, the same connections and tests as mentioned above can be made except those involving the wire *B* which does not exist here. Therefore only one-half the number of tests can be made to get *c* and *d* and hence an accurate location of the fault cannot be expected.

Tables 1 and 2 give the results of tests on telegraph cables.

Fault 1 had 3 wires between *A* and *B*.
“ 2 “ 2 “ “ “
“ 3 “ 3 “ “ “
“ 4 “ 2 “ “ “

Fault 5 was a single displaced wire as illustrated in Fig. 4 and there were 4 wires between *a* and *c*. All the figures obtained are given in the tables so that persons interested in this subject can study them, noting the change of capacity for different connections.

TABLE II

No. of Fault	Length of cable	Actual distance to fault	Calculated distance to fault		Average error in feet	
			Other wires not grounded	Other wires grounded	Other wires not grounded	Other wires grounded
No. 1	1098 ft.	208 ft.	176.1 ft. 234.5 ft.	189.9 ft. 205 ft.	— 2.7	—10.5
No. 2	1098 ft.	208 ft.	238 ft. 252.5 ft.	237.6 ft. 226 ft.	+37.	+24.
No. 3	1021 ft.	557 ft.	——	569.8 ft. 581.5 ft.	——	+18.6
No. 4	1021 ft.	794 ft.	823 ft. 803 ft.	818 ft. 819 ft.	+19.	+24.5
No. 5	987 ft.	265 ft.	193.6 ft. 203.8 ft.	209.6 ft. 181.9 ft.	—66.3	—69.2

Table II gives the errors in feet; they are sometimes + errors and sometimes — errors, thus tending to show that inequalities in manufacture are probably largely the cause of the discrepancies.

Telephone cables. Telephone cables are made up of twisted pairs, and when they are jointed no attempt is made to connect the pairs in any definite order. In fact most of the telephone companies mix the pairs of the different layers up as much as possible, thereby making the capacity of the pairs more uniform and the cable more efficient for telephone service. On account of this method of installation, it is more difficult to locate split pair faults accurately.

Fig. 5 illustrates what is meant by a split pair. The wires *C* and F are connected straight through the cable, but D and E are cross-connected. If those two pairs are used for telephone service there will be more or less cross-talk, depending upon the location of the transposition. Hence the need of locating the joint where the wrong connection has been made and rectifying the mistake. Some of the methods which have been used for locating split pairs are not reliable, giving only a rough approximation.

After a consideration of the former work presented in this paper, it will be seen that the same general methods may be employed provided we can make the capacity b fairly uniform throughout thec able, and then either measure it directly or else eliminate it from equation (9). The first can be accomplished

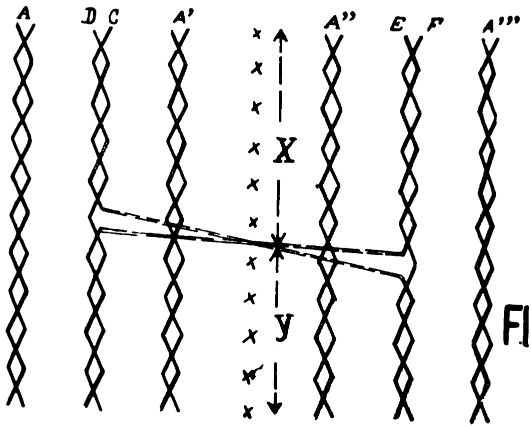


FIG. 5

fairly well by grounding all the wires in the cable except those used in the test, and b can be eliminated from equation (9) as will now be shown.

Referring to Fig. 5, A, A', A'', and A''' represent four good pairs. C, D, E, and F represent the split pairs, C and F being connected correctly, D and E being cross-connected. The capacity between the wires of the individual pairs A, A', A'', and A''' should first be measured and the average taken as the value of a. It is not absolutely necessary to take just four pairs, but enough should be measured to insure a good average result.

As in the case of telegraph cables, we will let the capacity

$$\frac{CD + EF}{2} = c \text{ and } \frac{CE + FD}{2} = d.$$

Now by referring to Fig. 5 we can say that the capacity b is equal to the capacity $C\,E$ throughout the distance x added to the capacity $C\,D$ throughout the distance y. Now as a is the capacity of a pair we can say that a equals the capacity $C\,D$ throughout the distance x added to the capacity $C\,E$ throughout the distance y. This gives the relation $b = c+d-a$. Substituting this value of b in equation (9) we get

TABLE III

RELATIVE CAPACITIES = R IN FIG. 1.

Test between wires	Fault No. 1	Fault No. 2	Fault No. 3	Fault No. 4	Fault No. 5		Fault No 6	
	m	m	m	m	m	n	m	n
A	555	523	527	554	827	827	827.5	826.5
A'	537	530.5	540	576	832.5	833	839	838
A''	538	519.0	618	589	837	838.5	848.5	846
A'''	536	547.5	592	566	830	830	831.0	829.5
Average a	541.5	530	569	571.2	831.6	832.1	836.5	835
$C\,D$	505	472	466	478	681	710	762.5	770
$E\,F$	468	485	504	498	686.5	716	766	773.5
Average c	486.5	478.5	485	488	683.7	713	764.3	771.8
$C\,E$	497	469	469	479	756.5	764.5	679.5	714.5
$E\,D$	466	480.5	490	492	747.5	756.5	674.5	707.5
Average d	481.5	474.8	479.5	485.5	752	760.5	677	711

TABLE IV

No. of fault	Length of cable	Actual distance to fault	Calculated distance to fault		Average error in feet	
			Other wires not grounded	Other wires grounded	Other wires not grounded	Other wires grounded
No. 1	586 ft.	293 ft.	305.6	——	+12.6 ft.	——
No. 2	586 ft.	293 ft.	303.1	——	+10.1 ft.	——
No. 3	586 ft.	293 ft.	302.3	——	+ 9.3 ft.	——
No. 4	586 ft.	293 ft.	297.3	——	+ 4.3 ft.	——
No. 5	1155 ft.	433 ft.	404	433.7	—29. ft.	0.7 ft.
No. 6	1155 ft.	759 ft.	797	765	+38. ft.	6.0 ft.

$$x = \frac{(a-d)\,L}{2a-(c+d)} \tag{12}$$

Which is the formula to use for a split pair in a telephone cable?

Referring now to Tables III and IV, faults No. 1, No. 2, No. 3, No. 4 were purposely made in 585 ft. of 203 pairs No. 19 cable.

There were two, three, four, and five pairs respectively between the faulty pairs of each fault. It is evident that the farther the faulty pairs are apart the nearer correct is the fault location. Tests were not made in this case with all the wires except the test wires connected to the lead cover, or else a less error in feet would probably have been obtained. Faults 5 and 6 were in the No. 13 pairs of a combination cable consisting of 15 pairs No. 19 and 10 pairs No. 13.

It is a notable fact that the error in feet is much smaller when all the wires not used in each test were connected to the lead cover than when all wires were free.

Some tests were made using a ballistic galvanometer and the discharge deflection method and good results were obtained. This method would probably be used the most in practice, but there are testing sets where the resistance method and a telephone are used; these are especially suitable for locating faults of the kind herein treated. One of these designed by the writer is giving good satisfaction in commercial use.

Conclusions. Sufficient tests are not here given to enable anyone to tell how successfully such faults could be located in practice, but the writer is of the opinion that relatively better results might be obtained, because the general average of many sections of cable would tend towards capacity uniformity, especially in telephone cables. The tests on telephone cables here recorded average better than those on telegraph cables. The methods would probably have a wider range of usefulness in telephonic than in telegraphic engineering work.

A paper presented at a meeting of the Pittsburgh Section of the American Institute of Electrical Engineers, Pittsburgh, Pa., May 6, 1908.

Copyright 1908. By A. I E. E.

(Subject to final revision for the Transactions.)

CALCULATION OF THE STARTING TORQUE OF SINGLE-PHASE INDUCTION MOTORS WITH PHASE-SPLITTING STARTING DEVICES

BY I. E. HANSSEN

The starting torque of any induction motor is proportional to the product of the main field by the quadrature field, hence to the product of the main electromotive force by the quadrature electromotive force. The starting torque of a single-phase induction motor with a phase-splitting starting device can, therefore, be predetermined if the electromotive forces at the terminal are known.

If we have a Y-connected motor, we first calculate the starting torque which the motor would develop on a three-phase circuit; in this case the above product is $e^2 \frac{\sqrt{3}}{2}$ and the area of the electromotive force triangle is $e^2 \frac{\sqrt{3}}{4}$, where e is the terminal voltage.

The actual torque of the motor on a three-phase circuit is

$$T_3 = \frac{3\, e_0^2\, r_s}{Z^2\ 746}$$

where

e_0 = Impressed electromotive force per phase.

r_s = secondary resistance per phase reduced to primary terms.

Z = Total impedance per phase.

If the same motor is now connected with a resistance reactance starter as shown in Fig. 1, the electromotive forces at the terminals can be found as follows:

Referring to Fig. 2, lay of $O\,A$ and $O\,B$ representing the impedances $Z+Z_2$ and $Z+Z_1$, respectively. Draw a line in the direction $O\,D$, the angle $B\,O\,D$ being equal to $A\,O\,C$ and angle

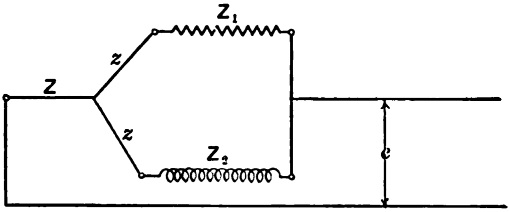


Fig. 1

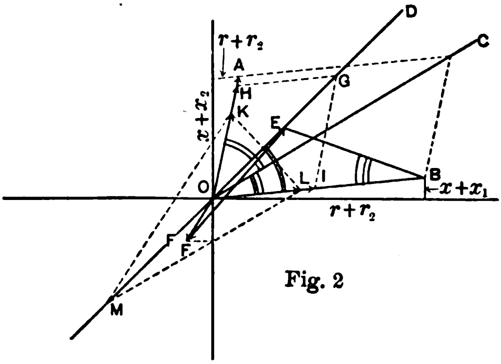


Fig. 2

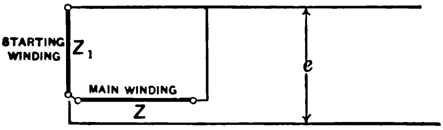


Fig. 3

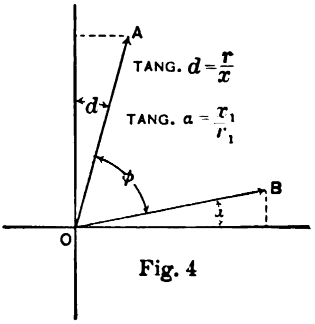


Fig. 4

e = line e.m.f.; r_p = primary resistance per motor phase; r_s = secondary resistance per motor phase reduced to primary; r = total resistance per motor phase reduced to primary; x_p, x_s and x corresponding values of leakage reactance; $Z = r - jx$ = impedance per motor phase; $Z_1 = r_1 - jx_1$ = impedance of one leg of starter; $Z_2 = r_2 - jx_2$ = impedance of other leg of starter.

$E\,B\,O$ to the angle $B\,O\,C$, $O\,C$ being in the direction of the resultant of $O\,A$ and $O\,B$. $O\,E$ is then the joint impedance of $Z+Z_1$ and $Z+Z_2$.

Draw $O F$ representing the impedance Z. $E F$ is then the resultant impedance of the motor and starter.

Divide this into the line voltage; this gives the total current, which is to be laid off along $O D$ to some convenient scale, giving $O G$; resolve $O G$ into $O H$ and $O I$, the currents in $Z Z_2$ and $Z Z_1$.

Lay off $O K = O H \times Z$ and $O L = O I \times Z$, representing the drop in the two motor phases connected to the starter. Lay off $O M = O G \times Z$, the drop in the third motor phase.

The triangle $K L M$ now gives the values and the relative phase relations of the terminal electromotive force.

The starting torque on a single-phase circuit is

$$T_1 = T_3 \frac{\text{area of triangle } K L M}{e^2 \frac{\sqrt{3}}{4}}$$

If the motor is delta connected use equivalent star values and proceed as above.

In case we have a motor wound as shown diagrammatically in Fig. 3, Z being the main winding and Z_1 the high resistance starting winding, we first find the starting torque of a two-phase motor having two windings like the main winding.

This is

$$T_2 = \frac{2 e^2 r_s}{Z^2 \, 746}$$

Then referring to Fig. 4, lay off $O A$ to represent the ampere-turns of the main phase, the direction being such that

$$\text{tangent } d = \frac{r}{x}.$$

Draw $O B$ = ampere-turns of starting winding,

$$\text{tangent } a = \frac{x_1}{r_1}.$$

Then the starting torque is

$$T_1 = T_2 \frac{O A \times O B \sin \phi}{(O A)^2}$$

DISCUSSION ON "THE DETERMINATION OF THE ECONOMIC LOCATION OF SUB-STATIONS IN ELECTRIC RAILWAYS", AT ATLANTIC CITY, N. J., JULY 1, 1908.

(Subject to final revision for the Transactions.)

C. J. Hopkins: On December 15, 1905, a paper was read before this Institute on the most economical location of substations for direct-current systems.* Mr. Werner's paper only differs from that, as far as I understand it, in its particular reference to single-phase systems.

Of course, we are all familiar with the form of curves given in Fig. 1. I would not criticise the accuracy of the formulas presented by Mr. Werner, but I question their general usefulness. As simple as it may sound, it appears to me that the most important feature in working out an electrification proposition is the proper consideration and formation of a train diagram, to represent what the service will be when the electrification is completed.

In the last paragraph Mr. Werner refers to the use of his formulas as obviating the necessity of solution by trial. This seems to imply that there might be a large number of solutions by trial necessary if that were the method resorted to, but in general there are only two or three practical solutions, and as a rule they have to be worked out in detail and carefully considered.

The specific purpose of this paper is to develop an equation for the number of sub-stations, but I do not believe that such a determination is simplified by resorting to any formula of a general nature, but rather is the result of practical consideration and sound judgment.

Gerard B. Werner: The paper to which Mr. Hopkins refers was typical of the method of solution by trial, by evaluating the annual charges for a different number of sub-stations. Now the adjustment of the cost of sub-stations and the cost of copper, considered as an economical problem, is quite definite, and my paper is an attempt to develop some formula to obviate the trial method.

The economic condition of the secondary distribution, whether it can be executed in the actual layout of the road or not, should be determined as a basis of reference. This consideration is the primary intent of the paper, and not the substitution of a formula for judgment for the handling of engineering problems of this character.

To the best of my recollection, Mr. Lincoln made a contribution to the proceedings of the International Electrical Congress in St. Louis in 1904 on a similar subject, and I have no doubt that he has some comment to make on this topic.

---

* "Some Considerations Determining the Location of Electric Railway Sub-Stations," by C. W. Ricker, *Transactions* A. I. E. E., Vol. XXIV, p. 1097.

P. M. Lincoln: I have not much to add to the discussion, although I have given this matter considerable thought. I am rather inclined to agree with Mr. Hopkins in his suggestion, that after having worked over this matter with a whole lot of formulas, the actual locating of sub-stations is not so much a matter of manipulation by formulas as it is a matter of judgment. It is safe to use the location obtained by formulas only when no other location is dictated by common sense.

DISCUSSION ON "COMPARATIVE TESTS OF LIGHTNING PROTECTION DEVICES ON THE TAYLOR'S FALLS TRANSMISSION SYSTEM", AND "STUDIES IN LIGHTNING PERFORMANCE, SEASON 1907." NEW YORK, MAY 19, 1908

(Subject to final revision for the Transactions.)

H. W. Buck: The valuable data presented to-night include the most comprehensive and systematic record of lightning disturbances which has been presented to this Institute. In the old days of electrical transmission most of the trouble we had to cope with was due to the station apparatus itself, as the insulation of the lines was relatively high. As line voltages have risen with the progress of the art, the insulation of station apparatus has risen in proportion. Presumably lightning stresses have remained constant, so that at the present time we have insulation in our stations which perhaps on the high-voltage transmissions is high enough to withstand the original lightning surges, and the troubles seem to be shifting out upon the line itself. I think that this is the most noticeable feature of this paper. During the storms spoken of in the paper, many insulators were shattered, poles were shattered, and some cross-arms burned, and so on, and yet only one transformer bushing was damaged within the station.

It has conclusively been shown that these line troubles have been reduced by means of the overhead ground-wire. It is not only shown in this particular system, upon which we have the record to-night, but the experience over all this country with transmission lines, where the overhead ground-wire has been installed, shows similar corroborative evidence. There are perhaps three functions of this overhead ground-wire: it takes the direct stroke and it allows the induced charge to accumulate on the ground-wire instead of accumulating upon the transmission wire itself, so that when the cloud which induced this charge discharges itself through a lightning flash the corresponding charge of opposite polarity on the ground-wire can discharge itself through the ground connections on the pole, instead of having to spill over the insulators. Another important function of this overhead ground-wire consists in shielding the transmission wires from induced potentials between phases, due to neighboring lightning discharges, which are presumably of high frequency. The guard wire forms one side of the circuit and the ground the other, so that we really have a short-circuited shield against induction on the transmission wires—the ground and the shield wire being connected by electrical connections. If this theory is correct, it would seem to be a decided advantage to have two overhead ground-wires rather than one, a connection being made between these two shield wires at every pole. Then we should have a shielding effect in the vertical plane and also in the horizontal plane against induced potentials, between the phases in the transmission wires. These short-circuited loops in fairly close proximity to the transmission wires might represent some induced loss on the normal frequency of the transmission system, but I doubt if it would be enough to be very serious; whereas at the frequency of the lightning discharge the possible induced current might be high and give a decided shielding effect to the transmission wires.

The evidence of the spilling over of accumulated charge in the insulators seems to show that the actual magnitude of the momentary current in this ground-wire is very large. I think it would be interesting if some form of current-recording device could be installed experimentally in some of these guard wires, in order to give an indication of the magnitude of the currents. It would seem that along transmission lines there might be installed in circuit with the guard wire a crude form of ballistic galvanometer, which would give a record of the maximum current flowing in the guard wire during a storm. It would tend to indicate what conductivity ought to be established in these shield wires to take care of discharges, and would give valuable records.

It is quite noticeable from the records of this paper that lightning storms follow certain well defined paths throughout a region. There seem to be certain sections of the line which have borne the brunt of the lightning discharges; whereas other sections of the line have been practically free from trouble. I think that this accords with the experience of the Weather Bureau, in showing that lightning storms tend to progress along certain well-defined topographical paths. The frequent shattering of insulators as shown in these records indicates the desirability of developing some form of insulator which could withstand such a stress. The problem is a mechanical one, to get some material that can withstand the sudden application of the heat of an arc without it resulting in the insulator being shattered. It is not so bad to have a momentary short-circuit on a system, provided it blows itself out and leaves the insulator in comparatively good condition, but if every time a spill-over takes place the insulator is going to be destroyed, the operative difficulty becomes a serious one.

The horn arrester seems to have assumed a very important function in coping with the lightning problem. It is cheap and easy to insulate, and it can be put out of doors and withstand heavy rains without the insulation being impaired. It can also withstand very violent fireworks without the destruction of any valuable apparatus. In conjunction with the development of the horn arrester the problem of a good form of resistance is brought up. It seems to me that no really satisfactory form of resistance has yet been developed. The water rheostat is satisfactory under some conditions, but it is bulky and in cold weather there is trouble from freezing. A resistance ought to be developed which can withstand frequent discharges and which can carry without destruction, for periods of several consecutive seconds, a large dynamic current from the generators. With a resistance of this kind, sufficient surge current could flow to ground without necessarily shutting down the system.

It is interesting to note in this paper that certain discharges have been noticed on the secondaries of the transformers. This accords with my experience and with that of other engineers with whom I have talked. I have known of several instances where overhead lines pass through transformers into underground cable systems, where cable punctures have resulted simultaneously with thunder storms along the overhead lines. This indicates a possible necessity for having lightning-arresters of some form on the secondaries as well as on the primaries of the transformers, and I have noticed in this Taylor's Falls installation that there are such static dischargers on the secondary circuits.

It is also interesting to note that the tell-tale papers in shunt with the test choke-coils on the line have been punctured. This certainly indicates that choke-coils act as barriers to the progress of these lightning surges in spite of the fact that this has been disputed so many times. It is evident that choke-coils are a decided protection where they are installed.

In general, I believe that with steel construction adopted throughout a transmission line so as to eliminate the burning and shattering experienced in wooden construction, and with one or more guard wires installed along the line and over the transmission wires, that most of the serious lightning troubles on overhead lines will be eliminated.

P. M. Lincoln: In Figs. 11 and 12, Mr. Vaughan shows a number of curves the ordinates of which purport to give the static stress upon the insulators. I am not convinced that they do represent stress on those insulators. The ordinates of these curves are taken as the diameters of holes which were punctured in the tell-tale papers, and from that diameter is deduced the stress upon the insulators. I doubt whether the diameter of a puncture in the tell-tale paper is an indication of stress which is on the insulator; I think it an indication of the current that has passed through that tell-tale paper. The current may have come from a lightning stroke, but more likely it has come from the passage of the dynamic current.

J. F. Vaughan: The question of interpretation and graphic representation of these tell-tale papers is open to discussion. It has been given a good deal of thought in the preparation of the curves. The curves are drawn up to show graphically or pictorially the differences in stress on the insulators, spill-overs of static and dynamic discharges, and the scale assumed in plotting the curves is intentionally exaggerated in the lower ranges to facilitate comparison of the smaller punctures. The curves should be interpreted in the liberal spirit in which they were plotted; that is, as a general indication (as accurate as possible) of the relative activity of disturbances in each case.

P. H. Thomas: These papers differ from most lightning-arrester papers in that they are a simple record of practical operating results and not a compilation of theories. What is most needed in the study of the lightning problem is not so much theory and speculation as sufficient data and knowledge as to exactly how lightning affects a transmission line, so that an intelligent design can be made of protective apparatus, and so that the action of such apparatus can be properly judged. These papers go a long way toward showing the nature of the attack of lightning on the high-tension transmission line. Of course the data here recorded are not necessarily typical of all lines, but they indicate in a general way what may be expected to happen.

The interpretation of these punctures in the tell-tale papers is important. It will be found on examining the data that one storm occurred when no generator potential was on the line at all; in another case the potential went off in the early part of the storm. In these storms, then, at least during the major part of them, there was no actual generator potential on the line. The punctures in the tell-tale papers were just as severe during these times when there was no generator connected with the line as at any other time. Most of the punctures show, on examination, that the fibres of the paper are unburned even when large holes appear, showing them to be purely static discharges. In other words, the holes in the punctured papers are simple records of the static passing over the line.

I have not counted the total number of so-called spill-overs, but there must be hundreds of them. These are cases where a static discharge has passed over the wire to the pin from the surface of the insulators and not a capacity current to the pin. Only a small percentage of these spill-overs have injured insulators.

It is interesting to know that there has been very little disturbance of any serious character at the stations. Mr. Buck draws the conclusion that it is because the insulation of the station apparatus has been raised in relation to that of the line. It seems to me that the reason for the relative immunity of the stations is that the action is entirely local, the attack of the discharge being so sudden that it cannot pass more than a very short distance along the line. It is not of sufficient energy to cause any very great disturbance unless it should start an arc from the generator. It has been frequently assumed that the high potential on the line wire, due to lightning, is the release of a charge. This may be true, but I think the evidence points the other way. This is a matter which ought to be studied. The evidence suggests more strongly, it seems to me, the direct jumping to the line wire of electrical energy direct from the atmosphere and not the drawing of the charge from the ground.

V. E. Goodwin: The papers presented this evening are of special interest to me as I lived several years in Minneapolis and am quite familiar with the nature and severity of the lightning storms in that vicinity. I also inspected the Taylor's Falls system with Messrs. Vaughan and Neall during the preliminary testing of the line and protective devices. I was then of the opinion that it would be difficult to draw definite conclusions from the results they would obtain, as the system was so completely equipped that it would be impossible to differentiate the protective values of the various devices. I now believe that the papers presented to-night show conclusively that reliable data have at last been obtained on the effects of lightning on a transmission system and on the relative values of various types of overhead ground-wires.

The phenomenon regarding direct strokes of lightning on transmission lines mentioned by Mr. Vaughan has been reported on several other systems. One would naturally think that a line would be more subject to direct strokes after the wires are up than before. It seems probable that where the wires are up the charge dissipates over several insulators and poles and therefore does not splinter or burn the poles. I therefore question the ability of an investigator to determine from tell-tale papers whether a disturbance results from a direct or induced stroke of lightning.

The magnitude and intensity of many of the strokes indicated in these records give us a good idea as to what is required of a station lightning-arrester. The records indicate that the station arrester did not have sufficient discharge rate to relieve the line at those points, thus causing the horn arrester, which had a higher breakdown point, to discharge. In designing the latest types of arresters great care has been taken to avoid all series resistance and to increase the discharge rates. This feature has been thoroughly carried out in the aluminum type electrolytic arrester, by the use of large plate area and an electrolyte of very low specific resistance, thus giving low internal resistance and a maximum discharge ability.

It is interesting to note that many of the induced strokes on the Taylor's Falls line were highly concentrated and often of great intensity and volume. This is indicated by the storm of July 4, where one puncture 1.75 in. in diameter was recorded. The absolute protection of a line under such conditions becomes a very difficult problem. It is evident that one or two overhead ground-wires are of considerable assistance in shielding the line wires, but at best can only be of partial protective value. The problem of line-type lightning-arrester for this purpose involves the installation of several arresters per mile, and this, of course, is prohibitive in any transmission line of over 2300 volts. The only case where such arresters can economically be installed is at an exposed point, where experience indicates that the expense is warranted.

The Taylor's Falls tests indicate that during every storm a great many insulators spilled over without any resultant damage to the insulators or interruption to the service. I believe that the only means of entirely protecting an overhead power circuit lies in the development of an insulator which will not puncture, and, while having a fairly low spill-over, will not shatter. This perfection in the petticoat type of insulator is probably out of the question, but I believe it can be attained by a properly designed and proportioned insulator of the suspension or straw type. Such an insulator would be the equivalent of a line arrester at each pole or tower on the line.

E. E. F. Creighton: The two additional subjects I wish to discuss are the interpretation of tell-tale papers and the use of resistance type of horn arresters. The conditions which muddle the tell-tale records are: first, the impression of several static discharges on each paper before they are removed; secondly, the complete destruction of the static puncture holes by dynamic current. A fraction of an ampere of dynamic current for a half cycle of the generator wave is sufficient to destroy the static record. The authors were fortunate in obtaining records on an idle line. It may be suggested to those who are willing to aid in collecting data on this subject that the only data of great value in the study of lightning potential should be taken on an idle line, and furthermore should be collected on moving tapes by clockwork so as to separate the punctures due to each cloud discharge.

The value of the resistance type of horn arrester for discharging lightning increases as the value of series resistance decreases. On the other hand, the disturbance that one of these arresters may cause on the line increases as the series resistance is diminished. The menace resulting from a discharge through one of these arresters to ground may be either one of two effects, or both. First, the arrester may take sufficient current to overload the circuit-breaker. Opening switches under overload conditions should be avoided as much as possible, to say nothing of the interruption of service. Secondly, if the resistance is sufficient to prevent overloading, there may be a menace to the insulation by the operation of one phase only, especially on an insulated neutral system. It requires about one to two seconds at best for the arc to rise on the horns and go out. During this interval the arc varies from a short length to a very long length, and if there is a possibility of setting up a surge on the system this arc is most likely to produce the condition. On any particular system these arcs may occur repeatedly with impunity, whereas on another system the surge conditions will be such as to cause a destruction of apparatus on some other part of the system. To illustrate this two examples are herewith given.

On a 17,000-volt, 60-cycle, delta-connected system a single gap in series with enough resistance to limit the current to 0.5 ampere was connected between line and ground. Even with this high resistance all five of the arresters in the station on three feeders discharged continuously so long as the arc played across the gap to ground. A lightning-arrester of so limited a discharge would have little practical value, yet the surges caused by the discharge assumed dangerously high values.

As a second example, it is a common occurrence on cable systems to have several failures of cables after one has taken place, due, probably, to the surges set up during the first failure.

If one goes back over the history of the use of horn gaps with series resistance, the hope is always held out that an operator will finally obtain the right adjustment of resistance to give excellent protection without a resulting interruption of service. This has never been accomplished, and I think it can be shown that it never will be.

If we did not have the aluminum arrester it would be worth while working out the best conditions for the resistance horn gap arrester. A comparison of the two will show the limitation of the resistance horn type and the uselessness of the development. At 60,000 volts every ampere of discharge represents, roughly, 60 kw. per phase, or 180 kw. If an arrester will not discharge 100 amperes, I think it will not take the usual run of heavy discharges. With this rated discharge the generator would be called upon to furnish 18,000 kw. On the other hand, if an aluminum arrester is used, the energy taken from the generator will be less than 20 kw. and the rated discharge of lightning will be several hundred amperes at the same abnormal value of potential. The valve action of the aluminum arrester prevents almost entirely the flow of dynamic current at normal potentials and has a free discharge only at normal potential. This information is sufficient to show the futility of using the resistance type of horn gap arrester.

Furthermore, the current taken by the aluminum arrester from one phase to ground is leading, the same as the capacity current of the line or cable, and consequently one phase may arc continuously between line and ground without setting up surges on the system. It should be noted that the aluminum arrester actually maintains the voltage and thus prevents grounding the line conductor.

President Stott: In listening to the discussion, I recall the experience of eleven years ago with the Niagara transmission lines. I am not certain whether this was the first line equipped with overhead ground-wire, but at all events it was so equipped when it started. After a few months experience with the overhead ground-wires it was decided to take them down, as in the choice of two evils the lesser one seemed then to be the troubles due to lightning. This was due to poor material in the ground-wires themselves, as they were continually breaking and short-circuiting the lines. Now eleven years after, we hear that as the result of a most elaborate series of tests and investigations, the ground-wire gives the most certain protection. In a practical way there is every reason why it should. No one ever heard anywhere of an underground cable being struck by lightning. That means that if the ground itself is above the conductor the line is safe. We cannot possibly afford to put all transmission lines underground. A 60,000-volt underground transmission line two hundred miles long is absolutely impossible from a financial or commercial standpoint; but instead of putting the wires underground, we can in effect put the ground above the wires. The most perfect protection will be gotten where we have the most perfect network of ground-wires above our conductors. I think everything said to-night points to that fact.

Now to avoid ordinary troubles there must be a high factor of safety in all apparatus. Troubles with underground cables are almost unknown outside of mechanical damage and faulty joints, and the reason is that those cables are made with an extremely high factor of safety; for instantaneous voltage it is five; for continuous service, two. Just as it is with a human being, if a man is in a weakened condition every few germs that come along will give him a new disease; but if he is strong enough they won't affect him at all. We have got to make our system germ-proof, as it were, and have a very large factor of safety on the insulators. That, and the ground-wire, I think, is going to be the solution of our overhead transmission work.

J. F. Vaughan: I am sorry not to hear more discussion on the interpretation of tell-tale papers, as there is plenty of material for discussion. It is rather surprising that with the necessarily crude methods of measurement used there are not more apparent inconsistencies in the results. For instance, the three wires grounding the three pole pins through individual tell-tale spark-gaps are not more than a few inches apart and are mounted on porcelain knobs only, which might be expected to allow disturbances of such intensity as have been indicated by the papers to break across from wire to wire. This fact brings out one point which has not been touched on, and that is the lack of pronounced phase-to-phase disturbance, indicating that the main stresses which are between wires and ground do not greatly differ in the three wires.

N. J. Neall: I wish to emphasize again the points which I have made about insulators. According to the theory which I have advanced in my paper, suspended-type insulators would be subjected by lightning to greater disturbance locally than any insulator so far used for lower voltages, because I am assuming that there is no special overhead protection at all, and am taking the broad case. If the transmission wire takes this lightning charge, the charge must get to the ground some way or other, and the only place at which it could do so would be presumably by way of the insulator support. The suspended type insulator has not come into the Taylor's Falls problem, and we have no data respecting it; but if insulators could be studied with reference to the equivalent spark-gap we should probably find certain explanations of the phenom non at which we can now only guess. I think that is a point on which the Institute should have the fullest possible information, if not from a practical reason, certainly in connection with the advancement of the art, and, perhaps, indirectly, of the science

V. D. Moody (by letter): In a paper presented at a recent meeting of the Institute,* Messrs. Rushmore and Dubois recommended for insulator protection steel rods with ends pointed, bolted to the vertical members of the towers and projecting above the highest point of the line. This method of protection was freely criticized, but my experience is that this type of arrester is highly valuable.

Several years ago this type of arrester was used on the Winnipeg hydroelectric installation at Winnipeg, Canada. The transmission line was 65 miles long, delivering about 20,000 h.p. at 60,000 volts, 60 cycles. From the power house to the substation duplicate transmission lines of No. 00 B. & S. hard-drawn cable, with a hemp centre, were run in duplicate on steel towers. This line crosses the Winnipeg river with a span of about 760 ft., on towers 72 ft. high, each weighing about 6 tons, with a sag in the line of about 23 ft. at 50 degrees. The standard towers are 40 ft. high weighing about 2400 lb., spaced 500 ft. apart with a sag of about 14 ft. at 50 degrees. There are four railroad crossings. At Winnipeg, this line crosses the Red river with a 1100-ft. span, the towers are 105 ft. high with a line sag of 45 ft. at 50 degrees. These towers weigh 15 tons. The railway and river crossing towers are on concrete footings, and are grounded with a ground plate. This transmission line has 10 complete transposition spirals and is paralleled by a telephone line of No. 8 B. & S. hard-drawn copper wire on porcelain insulators on the towers. The telephone line was transposed at each tower. The telephone line and transmission line insulators were made of the same kind of porcelain.

On all of these towers this steel-rod type of horn arrester was used. In operation it was found that the protection afforded was extremely valuable, as none of the high-tension insulators was punctured in several very severe lightning storms. In this country the storms are very severe in the summer months. In one instance five miles of telephone line was knocked down and insulators broken without breaking any of the line insulators, although the effects of the storm were felt in the sub-station by the throwing out of synchronism, momentarily, the 800 kw. motor-generator sets.

This line has now been in operation since June 1906, and has never had a shutdown. As the storms have been severe, I feel assured that these arresters are doing good work, as this is the only protection on this line.

It appears to me, that this type of arrester with a ground-wire and multigap station arresters with choke-coils will afford protection that can be relied upon.

---

* Transactions A. I. E. E., Vol. XXVI, page 425.

A paper to be presented at the 230th meeting of the American Institute of Electrical Engineers, New York, October 9, 1908.

Copyright, 1908. By A. I. E. E.

(Subject to final revision for the Transactions.)

HIGH-POTENTIAL UNDERGROUND TRANSMISSION

BY P. JUNKERSFELD AND E. O. SCHWEITZER

Among the many electrical developments of the day the most striking one, the most far reaching in its direct and indirect results, is the successful transmission of energy at greatly increased pressures. From present indications systems operating at potentials of 100,000 volts and over will not be uncommon in a few years, and none dare prophesy what further increase the future has in store. What this means to many communities from an economic and sociologic standpoint can readily be appreciated. Cheap power will enable present industrial communities to improve and new ones to build up in pleasant localities many miles from its source, whether coal or waterfall, and cheap traction will quickly carry their wares to market.

Within the confines of the largest cities the conditions are sometimes such that it is not advisable to carry these high potentials overhead. In such cases it may be necessary to place the conductors underground. The limitations of insulation and size have kept the transmission voltage for underground cables at about one-third that of overhead transmission, and while there has been a considerable advance in the art the approximate ratio of 1 to 3 seems still to be maintained. However, in large systems of underground transmission, insulation and size are not the only cable limitations. The line constants may become such that the cable is frequently subjected to dangerously high potentials. It therefore becomes advisable carefully to study the system so as intelligently to provide conditions for reliable service.

This brings us to the subject of our paper in which we shall discuss high-potential underground transmission with a view of pointing out some lessons taught by experience and tests and of suggesting further investigation and discussion. It is not the intention to discuss cable manufacture or in any detail the installation or protection of underground cables, as these matters have already received careful and thorough attention in other Institute papers. Nor is this paper in any wise to be an argument for underground transmission as against overhead transmission. Conditions are frequently such that overhead transmission is the only practicable method. The increasing use of very high potentials is tending to raise the boundary between high and low tension, but at the present time the dividing line is still generally accepted as 5000 volts.

Typical large cable system. This paper will, therefore, not deal with experience at pressures lower than 5000 volts. A typical system using high-potential underground transmission extensively is that of the Commonwealth Edison Company of Chicago and its experience will be cited principally. The system is fairly well known, having been described in more or less detail in Institute papers and discussions and in the electrical press. Suffice it to say that at present (September, 1908) the system consists of two generating stations (a third is in process of erection) with a maximum capacity of about 18,000 kw. and 100,000 kw. respectively, sixty-six 9000-volt, three-phase, transmission lines aggregating 272 miles, supplying forty-four sub-stations containing synchronous converting equipment almost exclusively. Three additional sub-stations and 68 miles of additional 9000-volt cable are now under construction.

There is also a 20,000-volt line eleven miles long connected to the 9000-volt system through step-up transformers and feeding railway and frequency changer sub-stations located in an outer or suburban zone. Forty-four miles of additional 20,000-volt underground lines are under construction, which will bring the total up to fifty-five miles. The entire cable system is shown in Fig. 1. This 20,000-volt system will be permanently supplied from 5000 kw., three-phase, step-up transformers connected delta to star with the neutral grounded. The standard size of 20,000-volt cable is 00, and of 9000-volt cable 0000 and 250,000 cir. mils. The 340 miles of 9000-volt cables supplying the densely populated inner zone form a so-called " radial system " while the 55 miles of 20,000-volt cable when completed will form two so-called " ring systems ", one supplying the more sparsely settled outer zone northward and the other southward.

The radial and ring systems are shown diagrammatically in Fig. 2. The principal station (Fisk St.) is equipped with steam turbines exclusively, four with a maximum capacity of 7500 kw. each and six of 12,000 kw. each. The generators are all star-wound and the neutral is grounded.

In February 1902 the 25-cycle, three-phase system of about 17 miles of three-conductor cable and seven synchronous converter sub-stations was raised from 4500 to 9000 volts, the equipment and cable having been installed with this change in view. This transmission system was first put into service in August, 1897. The greater part of the cable at the time of the change to 9000 volts was 00, some 0 and about one-fifth of 0000 size. The insulation on the original 4500-volt cables consisted of 5/32 in. inner wall of paper around each conductor and an outer wall 3/32 in. thick surrounding all three. The thickness of the lead sheath was ⅛ in. In the 9000-volt cable the thickness of the paper insulation was finally standardized at 6/32 in. and 4/32 in. respectively. The increase per year in mileage of cables operating at 9000 and at 20,000 volts is shown in Fig. 3.

Other early cable systems. Some of the high-tension cable systems in operation or under construction in 1897, when the transmission system in Chicago was first put into service at a lower voltage, were the following: Brooklyn Edison Company, 6600 volts (1897); New York Edison Company, 6600 volts (1898); Niagara Falls Power Company in Buffalo, 11,000 volts at end of overhead line (1897); the Metropolitan Street Railway, New York, 6600 volts; Twin City Electric Company of Minneapolis, 12,000 volts (1898). Soon after came Manhattan Railway, New York, 11,000 volts; Providence, Rhode Island, 12,500 volts; Milwaukee, 13,200 volts; and St. Paul, 25,000 volts (1901). The cables of the St. Paul Gas Light Company were two in number and formed the receiving ends of two parallel 25,000-volt, three-phase, overhead transmission lines 30 miles long. Each cable was about three miles long; one had rubber insulation and the other paper. Cable manufacturers at that time generally offered to make cable to withstand 30,000 volts pressure for individual lines, but for a network about 15,000 volts was considered the safe limit. About a year later this limit had apparently advanced to about 22,000 volts.* The insulation used on these various cables might be of interest and is given in Table 1.

---

* Fisher, A. I. E. E. Trans. 1903, page 440.

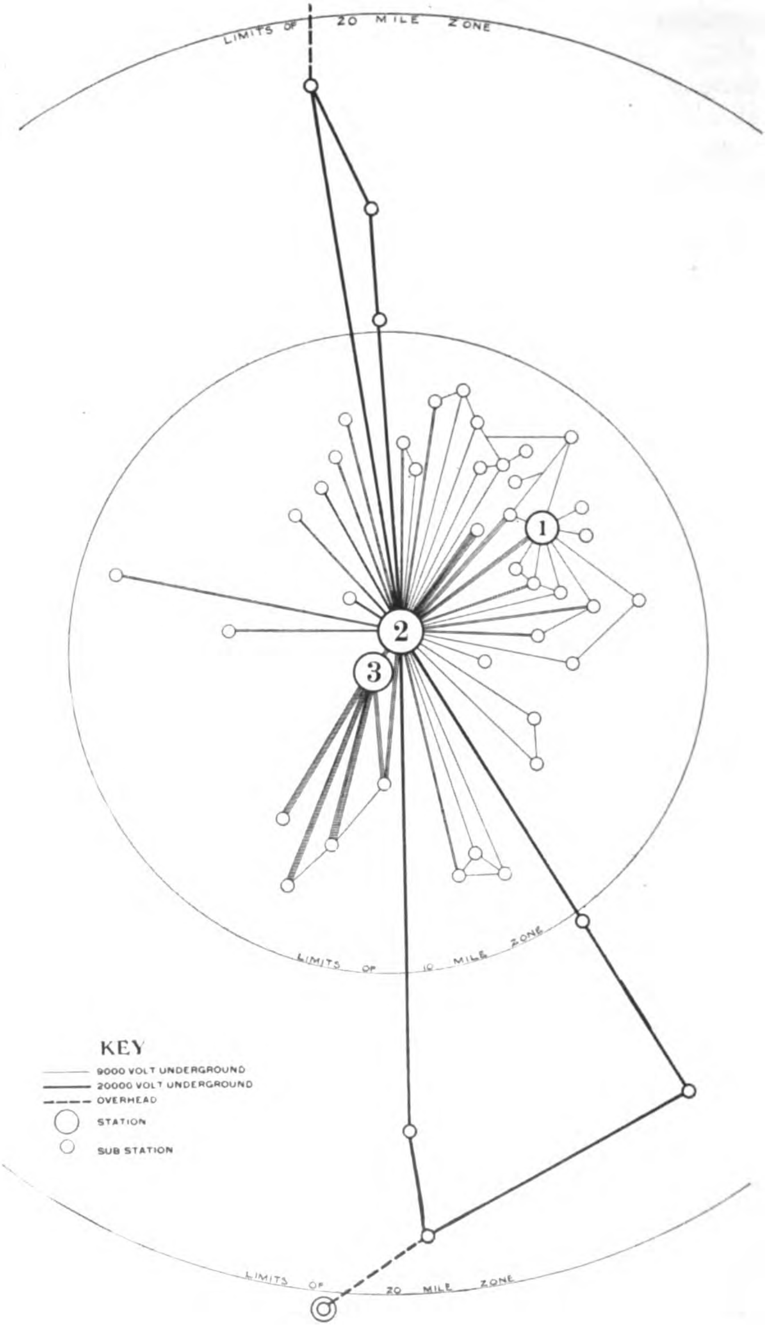


FIG. 2.—Diagram of 9,000-volt radial system and 20,000-volt ring system showing number of lines and sub-stations in each zone.

Experience. The early experience in Chicago and elsewhere showed the necessity for avoiding sharp bends and for using extreme care in making the splices. A small number of burnouts occurred during the first year's operation at 9000 volts, and nearly all were due to sharp bends or to moisture at the joints. In order to determine how quickly moisture in a cable causes a breakdown, after it has entered through an opening in

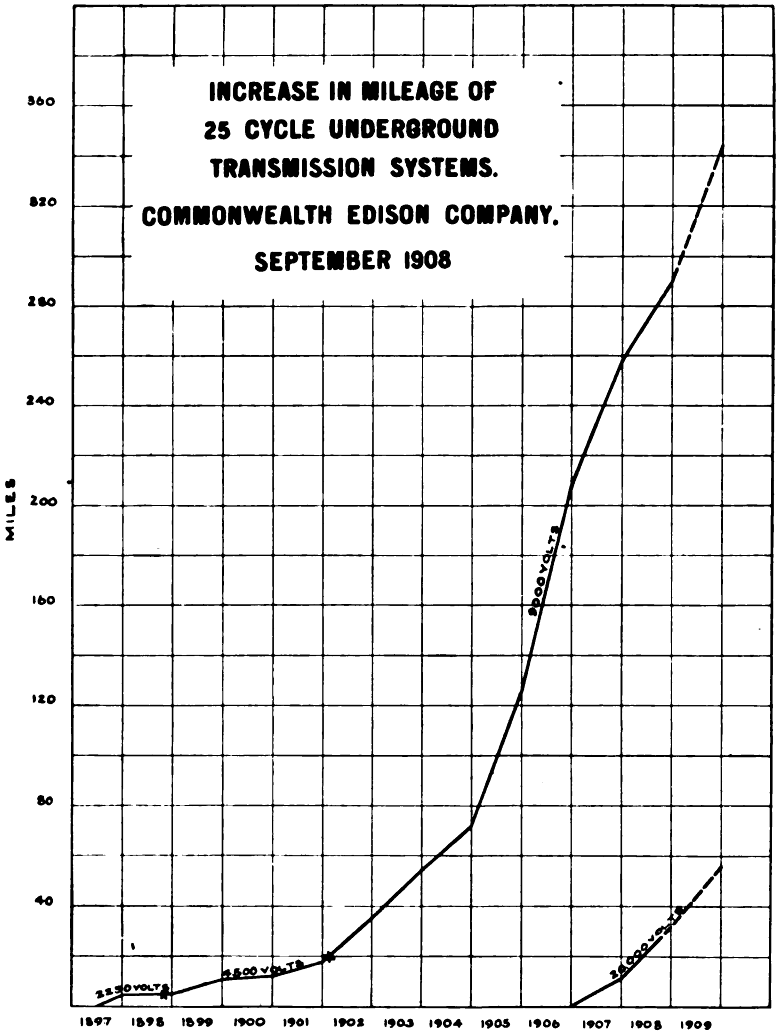


FIG. 3.

the sheath, in 1903 Mr. Burch* of Minneapolis made some interesting experiments. He found that it usually requires from a day to a week for the moisture to work down sufficiently to cause a burn-out. Paraffine had up to this time been used at the joints and in the terminal bells, but being hygroscopic in effect, due to voids left after cooling, it was not satisfactory at the higher voltage. About this time some of the engineers of the company, after considerable study and experimentation, de-

TABLE I
TABLE SHOWING INSULATION USED BY DIFFERENT COMPANIES ON THREE CONDUCTOR HIGH TENSION CABLES.

FROM PAPER BY W. G. CARLTON IN 1902

COMPANY	LINE VOLTAGE	KIND OF INSULATION	THICKNESS OF INSULATION IN THOUSANDTHS OF AN INCH					
			OVER 1 CONDUCTOR	OVER 3 CONDUCTORS	BETWEEN CONDUCTORS	BETWEEN CONDUCTORS AND GROUND	PER 1000 VOLTS	
							BETWEEN CONDUCTORS	BETWEEN CONDUCTORS AND GROUND
NEW YORK-EDISON	6 600	PAPER	156	156	312	312	47	47
NEW YORK-METROPOLITAN	6 600	PAPER	218	125	436	343	67	52
NEW YORK-SUBWAY CO	11 000	PAPER	218	250	436	468	40	43
BUFFALO-NIAGARA LINES	11 000	PAPER	203	203	406	406	37	37
BUFFALO-NIAGARA LINES	11 000	RUBBER	281	—	562	281	51	25
CHICAGO-EDISON	9 000	PAPER	203	140	406	343	44	38
MILWAUKEE	15 000	PAPER	250	187	500	437	33	29
SAINT PAUL	25 000	PAPER	281	203	562	484	22	19
SAINT PAUL	25 000	RUBBER	218	156	436	374	17	15
PROVIDENCE	12 500	RUBBER	281	—	562	281	45	22

---

* Burch, A. I. E. E. Trans. 1903, page 433.

veloped a high-grade insulating compound which since then has been used exclusively on all high-potential work.

The splices are made up with great care and the compound is poured into the sleeve at a temperature of 150° cent. in a manner to exclude all moisture. The success of this work is evidenced by the fact that there have been but two failures in splices during the last five and one-half years and there are now some 3400 splices in the high-tension system. The compound-filled terminal bells were formerly made of brass cylinders with a cast-brass base, a substantial ground connection being made at the base. On some recent work a few bells made of a special impregnated concrete have been used with very satisfactory results. The proper protection of cables against damage due to burn-outs of adjacent cable has received considerable attention, and all cables in manholes are covered with split vitrified-clay tile cemented in. Entirely separate duct lines either on different streets or on opposite sides of the same street are provided so as to divide the energy along different routes when possible, so that all important sub-stations have at least two lines, each of which follows a different conduit route.

Semiannual potential tests were made at the beginning but were discontinued when the system became more extensive. The danger and liability of accident from these frequent high-potential tests were thought to more than offset the doubtful advantages derived. Since then testing has been limited to new, altered, or repaired cable which before being put into service is subjected to a test of double working voltage for one minute.

The record of cable trouble (Table II) for the last five and one-half years' operation shows that failure of cables thus far has really not been a very serious matter. The line protective devices are now so perfected that a cable burn-out causes little disturbance. Of the total of 44 cases recorded in the table only 4 seriously disturbed the system, and each one of these was aggravated by faults in the protective relays. We believe that these faults have now been eliminated. The records of other companies have also been reported as good. Thus the New York Edison Company[1] in the nine years (1898 to 1907) during which its cable system grew from three to 200 miles had a total of 66 burn-outs of which 38 were due to external causes, 18 at or in splices, 4 in bends, and 6 in the cable proper. The Cataract Power & Conduit Company of Buffalo[2] had a total

---

1. Torchio, A. I. E. E. Trans. Dec. 1907, page 1711.
2. W. S. Clark, A. I. E. E. Trans. 1906, page 209.

of four burn-outs in seven years (1899 to 1906) on 12 miles of three-conductor rubber-covered cable operating at 11,000 volts; two were due to mechanical injury, one in a splice, and one in the cable. The rubber surrounding each conductor has a thickness of 9/32 in. and there is no overall jacket. The rubber shows no deterioration. Mr. Mershon[3] mentions four three-conductor cables each about two-thirds of a mile long operating at a pressure of 22,500 volts on which there had been but one

TABLE II
SUMMARY OF CABLE BURNOUTS
JAN. 1903* TO JULY 1-1908
9000 VOLTS

YEAR	MILES OF CABLE DEC 31	BREAKDOWNS				
		IN JOINT	IN BEND	IN CABLE	EXTERNAL CAUSE	TOTAL
1903	54	1		3	4	8
1904	71			2	1	3
1905	125		1	1	1	3
1906	209	1		2	2	5
1907	254			4	3	17
1908	JAN. 264		1	3	4	8
TOTAL		2	2	15	25	44
20000 VOLTS						
1907	11				1	1
1908	11	1		2	—	3
TOTAL		1		2	1	4

* DURING THE FIRST YEAR'S OPERATION AT 9000 VOLTS IN 1902 THERE WERE SEVERAL BREAKDOWNS IN JOINTS AND IN BENDS BUT THE TROUBLE RECORDS, UNFORTUNATELY, ARE NOT ENTIRELY COMPLETE.

---

[3] Mershon, A. I. E. E. Trans. 1904, page 610.

case of trouble in three years and that at a poorly made splice. The terminal bells on these cables are made of hard rubber.

On the 20,000-volt line in Chicago, which has now been in service about 15 months and which was an initial installation at this higher pressure, there have thus far been a total of 4 burn-outs, one of which was due to a mechanical injury, one to moisture in a poorly made joint, and two were in the cable itself.

Investigations. It will be seen, therefore, that the experience with high-potential cable has not been such as to cause alarm. The most frequent sources of trouble are from without, and of these electrolysis is apparently the most persistent. However, with rapidly growing systems the destructive effect and danger of breakdowns tends constantly to increase, and it becomes advisable to forgo complacency for a while and to look into the system with inquisitive eyes to see just what is going on.

It was this desire to know more about possible dangerous potential rises so that proper safeguards against them could be provided, if found necessary, that led the Commonwealth Edison Company to undertake a series of spark-gap and oscillograph investigations, the principal results of which thus far obtained are described in this paper. A further purpose of the tests was to obtain information regarding these high-voltage systems for use in their further development. The investment required for such 20,000-volt and higher transmission cable system is very large; it therefore becomes all the more imperative to know that such investment is a safe one commercially.

Tests on 9000-volt system. About a year ago a series of oscillograph tests was started on the 9000-volt system to determine whether or not resonance existed in any part of it, or if dangerous potential rises occurred from any other cause. The oscillograms obtained were taken at the Fisk Street station and included current and pressure waves for all principal switching operations, as well as several for a special cable connection in which resonance was sought. None of the records showed any appreciable excess voltage.

These investigations were later continued and expanded but no dangerous rises were found. Spark-gaps were installed at four different points of the system and their record carefully kept. The gaps consisted of needle points in series with which are resistance and fuse. They were connected between each phase and ground. These spark-gaps showed that there are frequent rises of about 70% and occasional ones of about 100% which apparently have no connection whatever with any switching. These occurred at the station and also in remote sub-stations. At times of cable breakdown, one or more of the spark-gaps invariably discharged at double potential[1]. With grounded systems cables break down first between a phase conductor and ground. When the protective devices fail to act properly, as they did occasionally before recent improvements were made,[2] the arc continues until it is communicated to one or both of the other phases. The effect on the system is then far more severe. Such occurrences were, however, the exception rather than the rule. When, during a breakdown, one or two of the spark-gaps discharge it is on the phase or phases other than the one on which the burn-out occurs. Sometimes all three of the gaps discharge during cable trouble, but not simultaneously. It is quite probable that the potential rises evidenced by these discharges are due to magnetic effect in the generators as much as to surges in the cables. There was only one case of cable breakdown which seemed clearly the result of a surge. During some arrangements which were being made at Fisk Street station to put a potential test on a bus-bar, one of the test leads accidentally came in contact with a live switch stud the door over which had been opened. This grounded one phase of the system through 50 ft. of heavily insulated No. 12 wire in series with the high-tension coil of a dead 150-kw. testing transformer. The heavy insulation was punctured in a number of places and the entire 50 ft. of test conductor was vaporized. No other damage was done in the station. A few seconds later one of the cables burned out at a point about one mile from the station.

The net result of this investigation indicates that at the present time the 9000-volt system is reasonably free from dangerous conditions as far as destructive potential rises are concerned. It also indicates the advisability of continuing to make tests on newly installed or repaired cable at double potential for one minute.

Tests on 20,000-*volt line.* Attention was then turned to the new 20,000-volt line in the attempt to learn what difficulties are to be met with there. On the diagram of this line in Fig. 4 are shown the locations at which current and pressure connections were made for the oscillograph. The numerals on the oscillograms refer to the corresponding ones of Fig. 4. Spark-gaps were connected to ground at points marked s.g. These spark

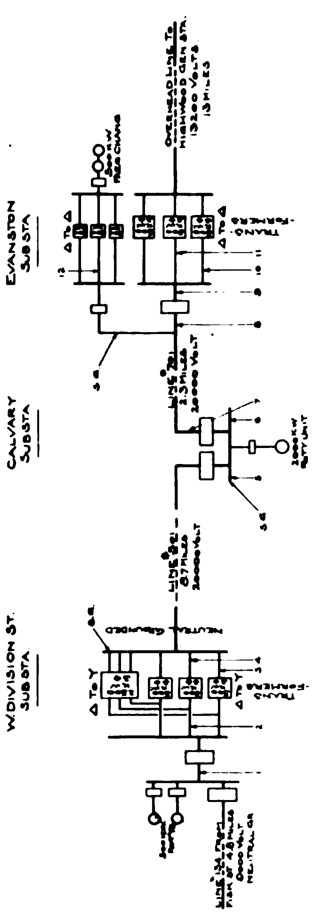
---

[1] Double potential when units with no neutral resistance were grounded and about 130% over potential when neutral was grounded through resistance (R = 2.6 ohms).

[2] June paper A. I. E. E. Chicago, R. F. Schuchardt.

FIG. 4

SUBSTATION CONNECTIONS OF 20000 VOLT LINE
SHOWING POINTS AT WHICH OSCILLOGRAMS WERE OBTAINED



S.G. - SPARK GAP

▭ - OIL SWITCH.

RECORDS OF OSCILLOGRAPH TAKEN AS FOLLOWS:

1. PRESSURE FROM SECONDARY OF POT TRANS ON A-B PHASE. 80 VOLTS
2. CURRENT FROM SECONDARY OF CURR TRANS. ON B PHASE.
3. PRESSURE FROM 11000 VOLT BUS A PHASE TO GROUND THROUGH 147000 OHM RES.
4. PRESSURE FROM 11000 VOLT BUS B PHASE TO GROUND THROUGH 147000 OHM RES.
5. PRESSURE FROM SECONDARY OF POT. TRANS A PHASE (RATIO 200/1) 55 VOLTS.
6. PRESSURE FROM 11000 VOLT BUS B PHASE TO GROUND THROUGH 147000 OHM RES.
7. PRESSURE FROM 11000 VOLT LINE CONDUCTOR B PHASE TO GR. THROUGH 147000 OHM RES.
8. PRESSURE FROM 11000 VOLT LINE CONDUCTOR B PHASE TO GR. THROUGH 147000 OHM RES.
9. PRESSURE FROM 11000 VOLT BUS B PHASE TO GROUND THROUGH 147000 OHM RES.
10. PRESSURE FROM SECONDARY OF POT. TRANS (RATIO 199/1) FOR PHASE SEE FIGS. 7 TO 15 INCLUSIVE.
11. CURRENT FROM SECONDARY OF CURR. TRANS. FOR PHASE SEE FIGS 7 TO 15 INCLUSIVE
12. CURRENT FROM SECONDARY OF CURR TRANS. B PHASE

gaps were first installed in the Evanston sub-station at the end of the line and originally set at 1.1 in. corresponding to 21,700 volts. During fifteen days *A* phase discharged eight times, *B* phase five times, and *C* phase six times. Five times during this period two gaps discharged at the same time (four on *B* and *C* and one on *A* and *B*). All other discharges were on one phase at a time. On only one day were there more than one discharge per phase, and on that day *B* and *C* phase gaps discharged together twice, the interval between the discharges being 18 min. With the exception of a single discharge on *A* phase, none of the discharges could be connected with any switching or other apparent source of disturbance. In this single case a heavy lightning storm passed over the overhead transmission line which is fed through transformers from the 20,000-volt line. It seems probable that a static charge passed from the line into the transformer and caused the rise which discharged on the *A* phase gap. Fourteen days' experience with a gap of 1.15 in. (22,500 volts) showed seven discharges on *A* phase, six on *B*, and five on *C*. The only coincident disturbances were as follows: one discharge on *A* phase when a steam-driven generator at the Highwood station was " synchronized "; *B* and *C* phases discharged together when a steam-driven unit in parallel with generator or frequency changer in Evanston governed poorly causing heavy cross-currents; one discharge on *A* phase when a steam-driven unit was disconnected at Highwood, and one discharge on *B* phase when steam-driven unit was shut down in Evanston. With the setting increased to 1.2 in. (23,300 volts) there were only five discharges recorded in four months, one on *A* phase, two on *B* phase alone, and one on *B* and *C* phases together. The simultaneous discharge on *B* and *C* phases occurred during a burn-out of the line, probably a breakdown of *A* phase to ground. One of the *B*-phase discharges took place when a connection between the 9000-volt coils of the *C* phase transformer at Division Street burned out. A further increase in gap setting was made to 1.25 in. and left for six weeks, during which time *A* phase discharged when the line broke down. *B* phase also discharged, but the connection with a disturbance could not be learned. A final increase to 1.3 in. was made. This corresponds to 25,000 volts. During three months there was one discharge on *A* phase and two on *C* phase, but here again no cause for the potential rises could be ascertained. Spark gaps were also installed at the step-up end of the 20,000-volt line in the West Division street sub-station during a test at that point. They were set at 1.1 in. and during the few hours that they were connected each of the phases discharged heavily at different times. Recently spark-gaps were installed at the Calvary sub-station. They are set at 1.1 in. and each phase has discharged heavily at times.

An attempt was made with the oscillograph to determine the relation between the potential rises and operating conditions. The oscillograph was connected at various times at the three switching points of the line and some records were obtained for switching operations. Unfortunately the time during which the line could be kept out of service for these investigations was so limited that only a few records could be obtained for each operation. It is recognized that in such a limited number (and especially where, as in most cases, only one phase pressure could be recorded) many disturbances may have escaped detection. However, many of the curves are of considerable interest and may serve to bring out more discussion. A number of them are therefore included in this paper. It will be noted that none of the oscillograms shows potential rises as high as those recorded by the spark-gaps. Had more oscillograms been taken, or had all phase pressures been recorded simultaneously, higher rises might possibly have been observed. However, the function of the spark-gap is clearly to detect high potentials, while that of the oscillograph is to show the character of the disturbance and its duration. The spark-gap watches the line continuously while the oscillograph records occurrences for but very brief intervals.

In the following Figs. the source of energy is always from the left, the opening or closing operation being performed on switch marked *S*. There being but one oscillograph and no pressure wires available, the records at the different sub-stations were not taken simultaneously. The apparatus was set up at one place and curves were obtained for the various operations. The apparatus was then moved to the next sub-station and the operations were repeated.

Fig. 5 is for closing and opening line No. 501. The current wave in the upper curve is the characteristic exciting current wave of a transformer when first energized. The logarithmic curve due to hysteresis is clearly shown. The dying of the pressures in comparatively slow oscillations when the line and transformers are disconnected is shown in the lower curves.

Fig. 6 gives curves for closing and opening line No. 701. A record obtained back at Division street for this operation at Calvary sub-station is given in the upper curve.

The next curves, Fig. 7, are for closing and opening the entire 11 miles of 20,000-volt line from Division street to Evanston. Curves of pressure were also obtained at the Calvary sub-station.

Fig. 8 shows curves for closing dead transformers on to a live bus-bar. The first rush of current in this case was nearly six times full-load current. An interesting curve is the one for West Division street showing the duration and amount of the current rush. The curve obtained on opening the switch to the transformers is also given.

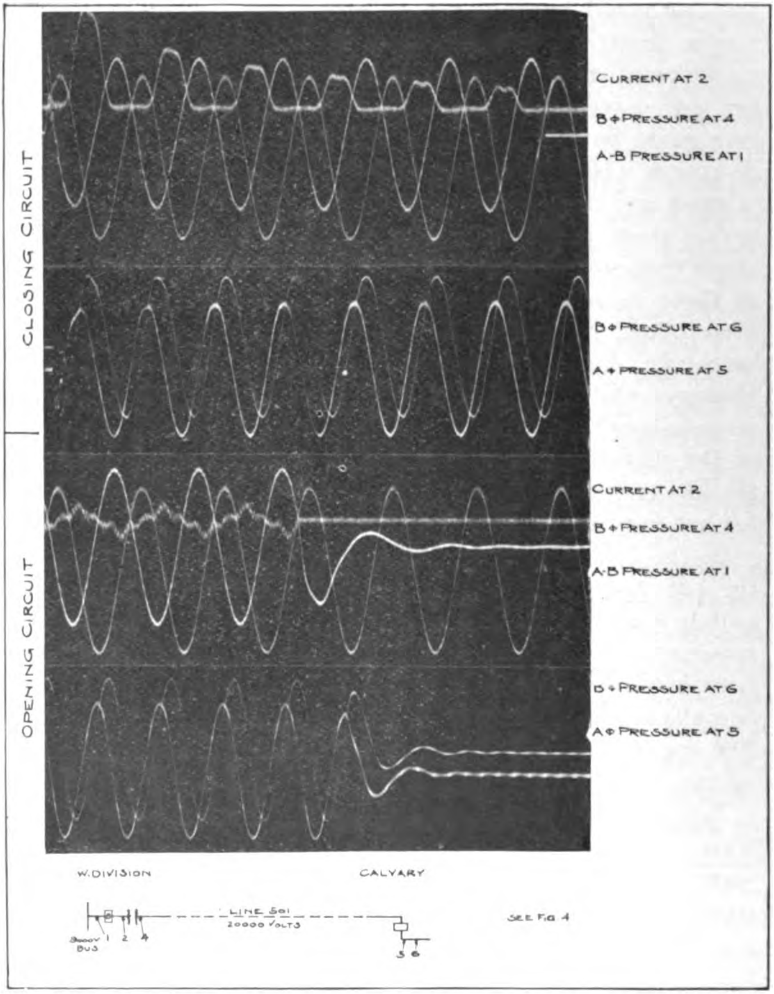


Fig. 5.

Line No. 701 was closed and opened with the transformers connected at Evanston and the curves for these operations are given in Fig. 9. Records were also obtained at Division street for the closing operation and are shown in upper curve.

The same operations were performed with the entire 11 miles of line, the records being given in Fig. 10.

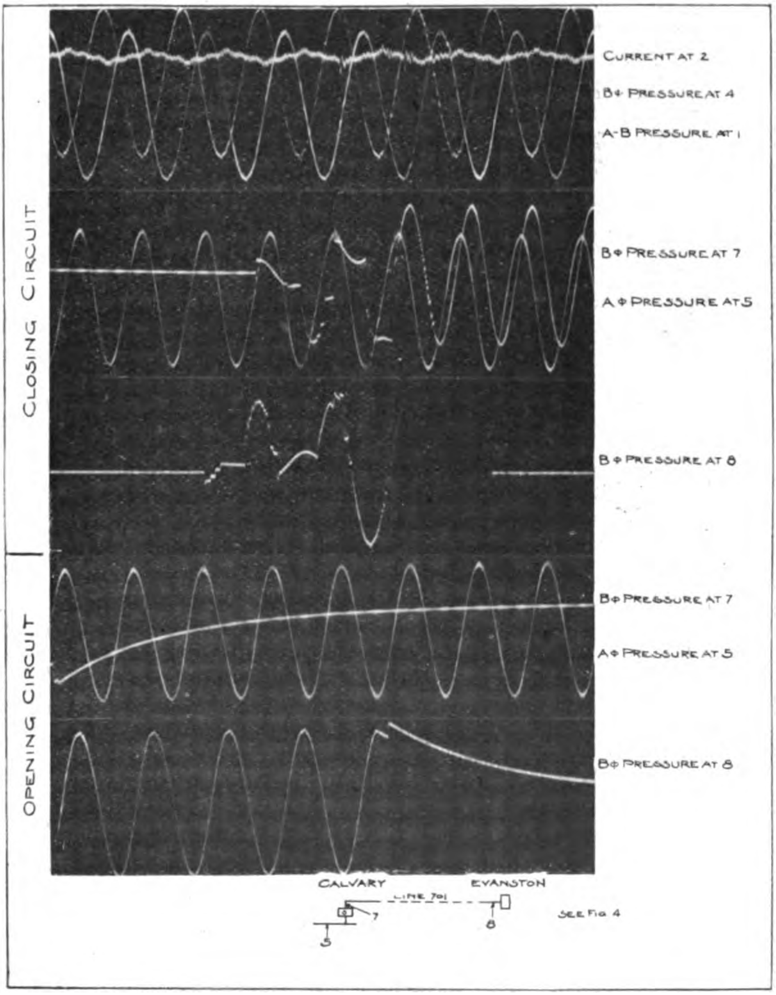


FIG. 6.

The motor of the frequency-changer set at Evanston is wound for 9000 volts, the line pressure being stepped down in three 200-kw. transformers. In Fig. 11 are shown curves obtained when closing these transformers to a live bus-bar. In the

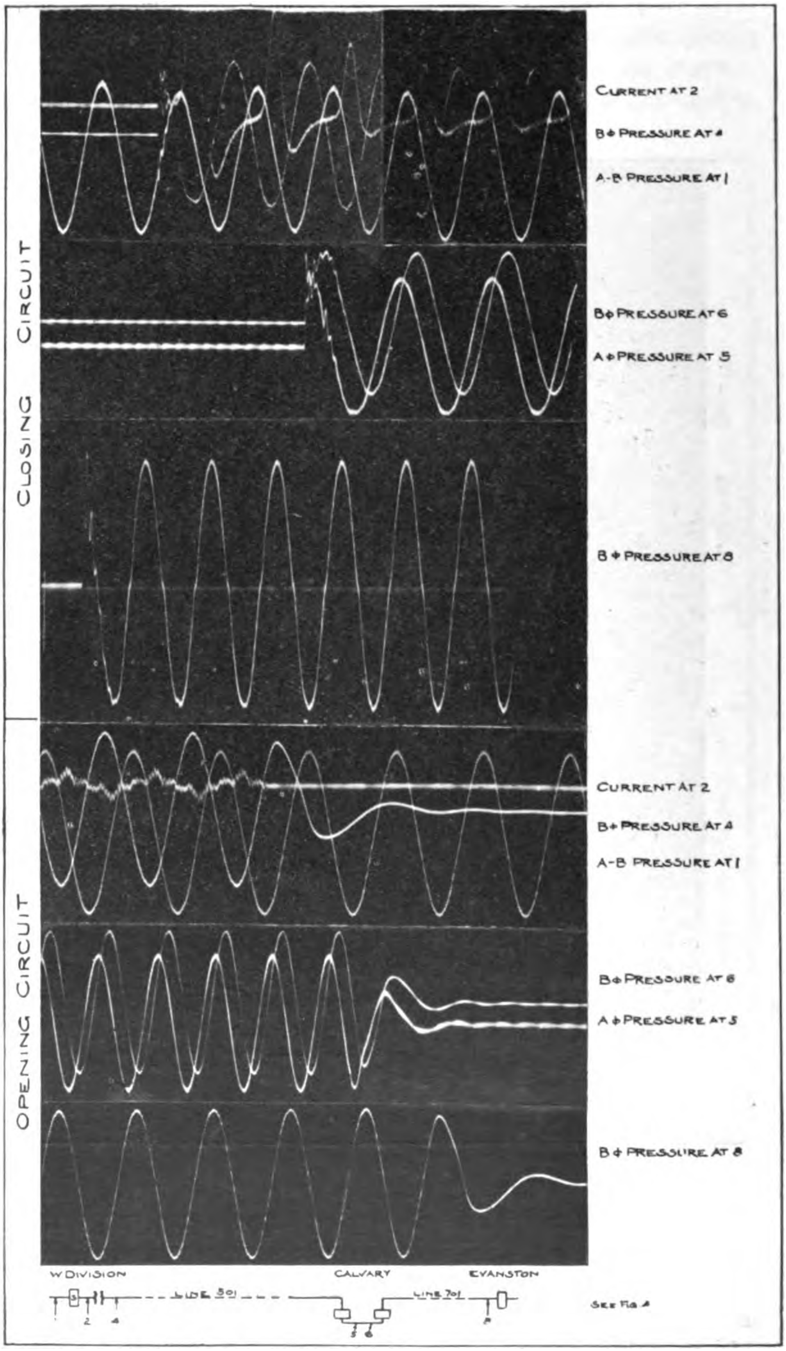

CLOSING CIRCUIT
CURRENT AT 2
B ϕ PRESSURE AT 4
A-B PRESSURE AT 1
B ϕ PRESSURE AT 6
A ϕ PRESSURE AT 5
B ϕ PRESSURE AT 8
OPENING CIRCUIT
CURRENT AT 2
B ϕ PRESSURE AT 4
A-B PRESSURE AT 1
B ϕ PRESSURE AT 6
A ϕ PRESSURE AT 5
B ϕ PRESSURE AT 8
W DIVISION
CALVARY
EVANSTON
LINE 501
LINE 701
1
2
4
5
6
8
SEE FIG 4

FIG. 7.

upper curve the transformers had previously been demagnetized by keeping them connected to the motor while being shut down until it had come to rest, the fields being kept excited. In the lower curve they had been disconnected at full pressure. The difference in current rush emphasizes the advisability of keeping the transformers connected to a dying machine when shutting down. This applies also to transformers of synchronous converter sets.

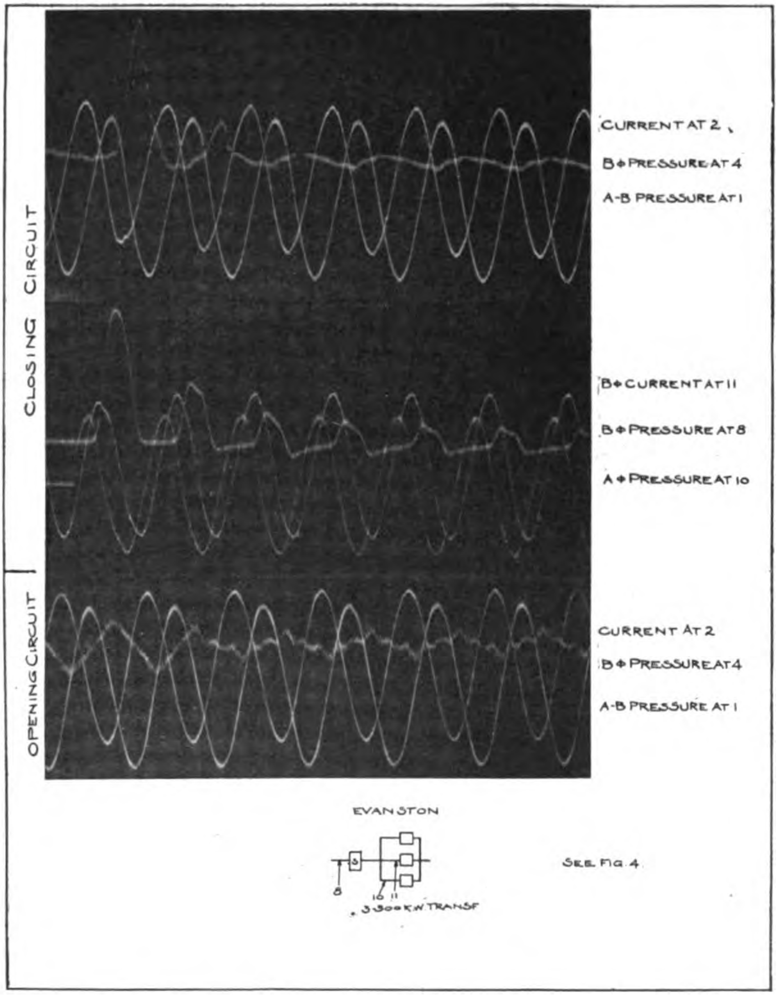


FIG. 8.

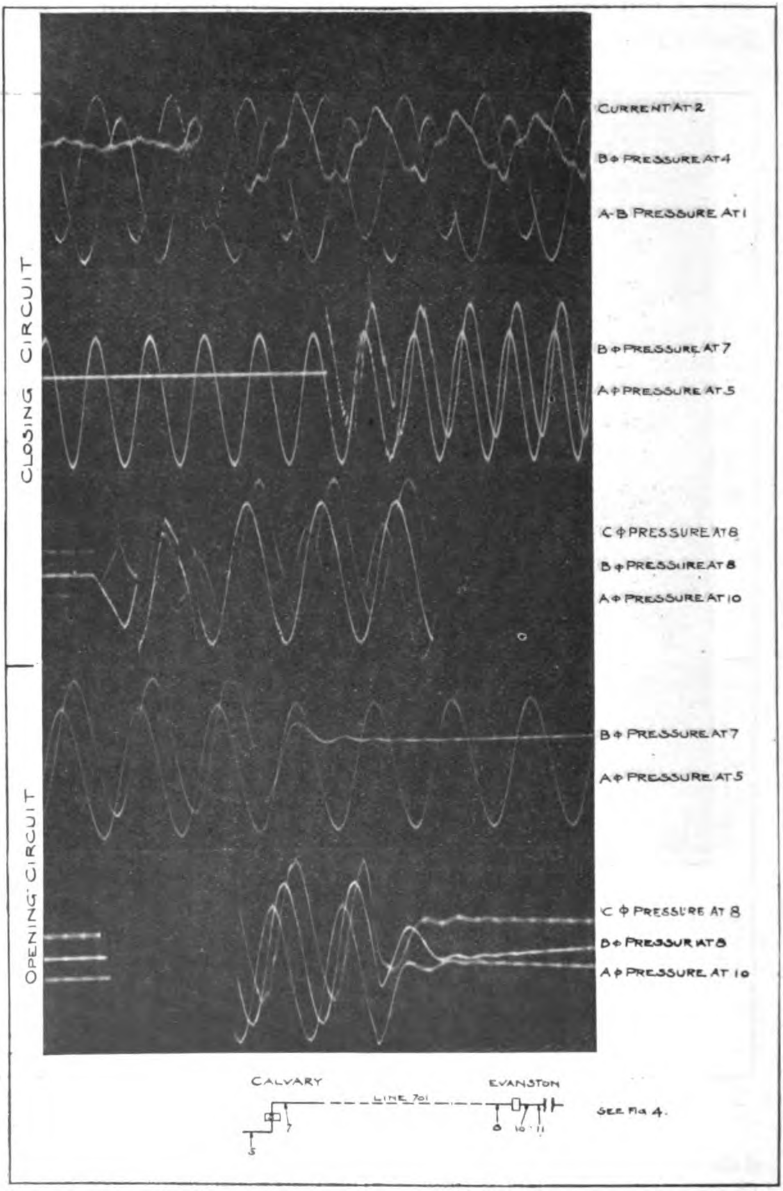

CLOSING CIRCUIT
CURRENT AT 2
B Φ PRESSURE AT 4
A-B PRESSURE AT 1
B Φ PRESSURE AT 7
A Φ PRESSURE AT 5
C Φ PRESSURE AT 8
B Φ PRESSURE AT 8
A Φ PRESSURE AT 10
OPENING CIRCUIT
B Φ PRESSURE AT 7
A Φ PRESSURE AT 5
C Φ PRESSURE AT 8
B Φ PRESSUR AT 8
A Φ PRESSURE AT 10
CALVARY
EVANSTON
LINE 701
5
7
8
10
11
SEE FIG 4.

FIG. 9.

The curves for starting the frequency-changer set from these transformers, Fig. 12, show no potential disturbance.

Two load-curves are given in Fig. 13 taken at Division street. The conditions were as follows: upper curve, volts 9000, amperes 85, kilowatts 600, power-factor 45%; lower curve, volts 9000, amperes 105, kilowatts 1600, power-factor 97.5%.

Fig. 14 shows curves obtained at Evanston when a steam-driven generator at Highwood was " cut in " with the line.

At the Evanston sub-station there are three 200-watt potential transformers connected in star with their neutral grounded on both primary and secondary. It will be remembered that the 20,000-volt line is grounded solid at the Division street transformers but at no other point. The oscillograph was placed in the neutral connection to ground of the Evanston potential transformers' primary and a current of 76 milliamperes was obtained, this amount remaining unchanged even when a resistance of 10,000 ohms was placed in series with the ground connection. The impedances of the three transformers have not been measured but their load is not balanced. In Fig. 15 this current wave is shown taken simultaneously with pressure. The wave for phase-to-phase pressure shows an unstable condition. A summary of the results shown by these oscillograms is given in Table 3.

Conclusions from investigations. From the spark-gaps on the 20,000-volt line we learn then that pressure-rises in excess of 100% occur occasionally. The oscillograms thus far obtained give no clear evidence of the cause, but the cable broke down three times in 15 months—two of these times in the cable itself, either as a result of these rises or of weakness developed by mechanical stresses imposed upon the cable at the time of installation. This record is reasonably satisfactory, as during the first year's operation we must expect to eliminate the weakest points. The second 20,000-volt line which will complete this northern ring is being installed at the present time. After it is put in service the investigation will be repeated. The spark-gaps are kept in service continuously. If dangerous potential rises still exist the remedy will be applied which, in the form of the aluminum arrester, is fortunately at hand. It is therefore quite prudent to state that 20,000 volts is a safe pressure for an underground system. Whether a higher voltage will be possible is a matter which has received and is receiving considerable attention.

Possible future developments. The awakened interest in and

TABLE III

SUMMARY OF DISTURBANCES SHOWN ON OSCILLOGRAMS

FIGURES 5 TO 15 INCLUSIVE

CIRCUIT TESTED			STEPUP TRANSF. AND LINE #501	STEPUP TRANSF AND LINES NO. 501 AND 701	LINE #701 ONLY	LINE #701 AND 3-500 K.W. TRANSF	STEPUP TRANSF. LINES No. 501 & 701 AND 3-500 K.W. TRANSF.	3-200 K.W TRANSF.		3-500 K.W. TRANSF.
								DEMAGNETIZED	NOT DEMAGNETIZED	
CLOSING SWITCH	AT SWITCHING POINT	BUS PRESSURE	SLIGHT OSCILLATION	12 % DROP	SLIGHT RISE	SLIGHT OSCILLATION	DROP	NO RISE	NO RISE	15 % DROP
		LINE PRESSURE	SLIGHT OSCILLATION	50 % RISE	OSCILLATION FOR TWO ~	55 % RISE	36 % RISE	NO RISE	NO RISE	15 % DROP
		CURRENT	127 %	140 %	——	300 %	200 %	200 %	500 %	600 %
	AT INTERMEDIATE POINT	PRESSURE	——	40 % RISE	——	——	50 % RISE	——	——	——
	AT RECEIVER END	PRESSURE	40 % RISE	50 % RISE	OSCILLATION FOR THREE ~	10 % RISE	SLIGHT OSCILLATION	——	——	——
		CURRENT	——	——	——	——	400 %	——	——	——
OPENING SWITCH	AT SWITCHING POINT	BUS PRESSURE	NO EFFECT	NO EFFECT	SLIGHT OSCILLATION	SLIGHT OSCILLATION	——	——	——	15 % RISE
		LINE PRESSURE	DIED DOWN IN COMPARATIVELY SLOW OSCILLATIONS WHERE TRANSFORMERS WERE CONNECTED TO LINE. WHERE LINE ONLY WAS OPENED, A SLIGHT PRESSURE RISE OCCURRED AND THE LINE THEN DISCHARGED THROUGH THE HIGH RESISTANCE OF THE OSCILLOGRAPH CIRCUIT.							
	AT RECEIVER END	PRESSURE								
CURVES SHOWN IN			FIG. 5.	FIG. 7	FIG. 6.	FIG. 9.	FIG. 10.	FIG. 11	FIG. 11	FIG. 8.

growing demand for a "City Beautiful" means the ultimate removal of smoky chimneys, dirt producing factories, and in some cases of overhead lines from within the heart of the city. This will increase the demand for a means of economically transmitting energy underground in large quantities and in many cases for comparatively long distances. When that time comes, and the herald has already appeared above the horizon, the operating companies will ask of the manufacturer a cable successfully to withstand the higher pressures required for the service.

Another condition which brings about a demand for high-voltage transmission is the better efficiency at present obtainable from large generating units in large stations compared with small units in small stations. Recent improvements in turbine design are resulting in greatly decreased steam consumption, especially for smaller units. With a sufficiently high transmission voltage, however, it will in many cases be found cheaper to generate large quantities in a large station and transmit to the distant center where the load is comparatively small than to generate in a smaller station at that center.

Regarding the maximum cable voltage, Mr. E. J. Berg in his new book on "Electrical Energy" (page 50) says:

> With the present state of the art it would not be conservative to use a cable at more than say 25,000 volts between conductors although it is to be expected that at least with rubber covered cables, or cables with insulation of varying specific inductive capacity a much higher voltage can finally be used.

Mr. H. G. Stott stated in 1906 in a paper on "Underground Cables",* that in his opinion cable voltages of 44,000 could be used provided the neutral of the system were grounded, thus limiting the potential to ground to 25,000 volts. Cables have been made which in the factory have successfully withstood pressures as high as 80,000 volts or more for an hour, but they have not yet been made for commercial use at such pressures. In the Elektrotechnische Zeitschrift of July, 1907 (page 676) appeared an abstract of a paper by de Marchena discussing pressure limitations for cables in which he made the interesting statement:

> As at very high pressures, potential rises are expected to occur less frequently than at low standard pressures, the factor of safety could be

---

* Read before the American Street & Interurban Railway Engineering Association, Oct., 1906.

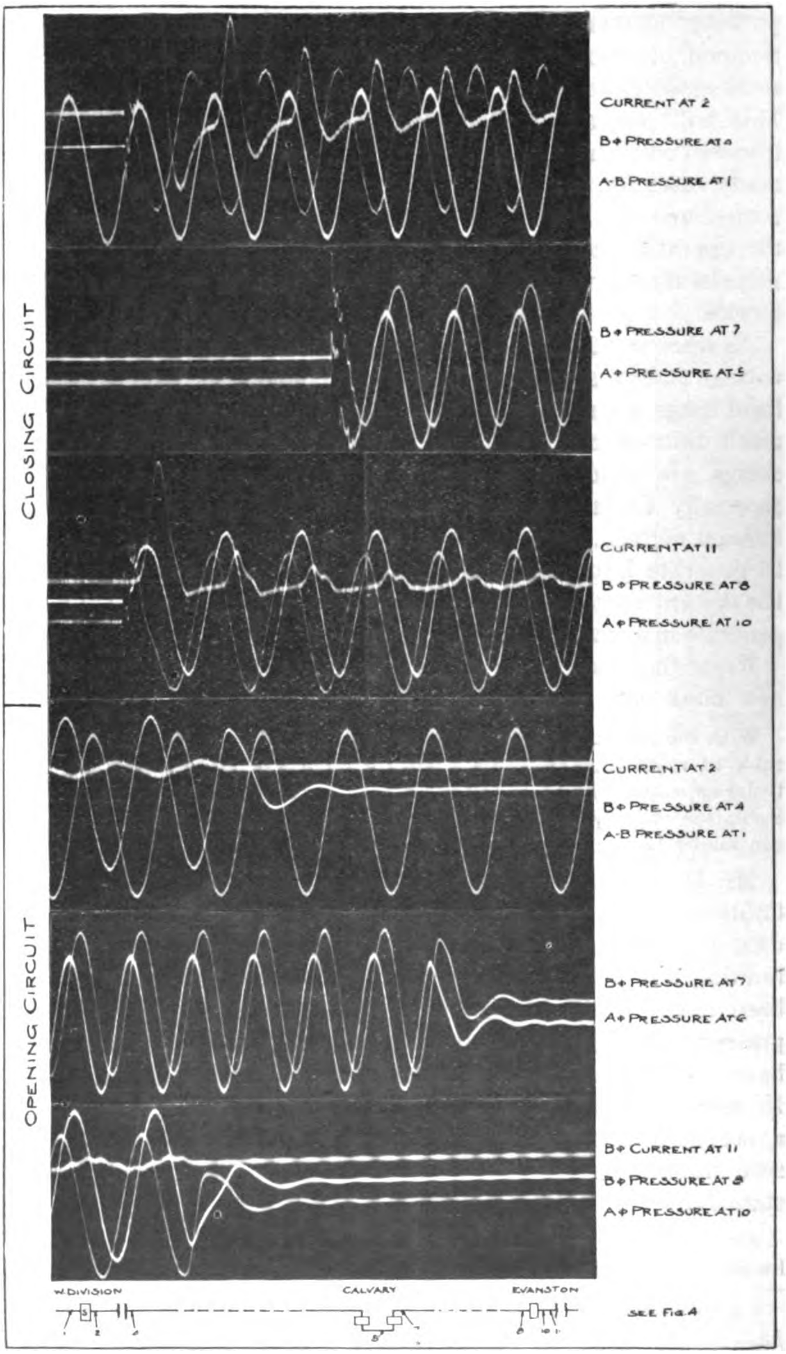

CLOSING CIRCUIT
CURRENT AT 2
B ϕ PRESSURE AT 4
A-B PRESSURE AT 1
B ϕ PRESSURE AT 7
A ϕ PRESSURE AT 5
CURRENT AT 11
B ϕ PRESSURE AT 8
A ϕ PRESSURE AT 10
OPENING CIRCUIT
CURRENT AT 2
B ϕ PRESSURE AT 4
A-B PRESSURE AT 1
B ϕ PRESSURE AT 7
A ϕ PRESSURE AT 6
B ϕ CURRENT AT 11
B ϕ PRESSURE AT 8
A ϕ PRESSURE AT 10
W. DIVISION
CALVARY
EVANSTON
SEE FIG. 4

FIG. 10.

decreased so that cables for a standard pressure of 40,000 volts may be manufactured especially for shorter distances.

It would be of interest to know de Marchena's reason for this statement. Messrs. Feldman and Herzog in the *Elektrotechnische Zeitschrift* for December, 1907 (page 1163) cite many cases of cable installations for voltages over 10,000 and some over 20,000 and also mention the very severe tests to which these cables were subjected. The general subject of high-tension transmission by underground cable is ably discussed from the manufacturer's standpoint by Mr. Richard Apt, Technical Director of the Berlin Cable Works (A. E. G.) in the *Elektrotechnische Zeitschrift* of Feb. 1908 (page 159). Single-conductor, concentric, and three-core cables are discussed, as well as the relative merits of different insulating materials and of aluminum for single-conductor cables. Mr. Apt prophesies that the single-conductor cable for very high pressures is the cable of the future. The installation for the County of Durham Electrical Power Distribution Co. Ltd., England, where about 40 miles of three-conductor cable was put into service for the first time for 20,000 volts is described. The cable is imbedded in troughs filled with an asphaltum compound. Telephone and pilot wires are placed under the trough. It is stated that this is the method generally employed in England for laying cables.

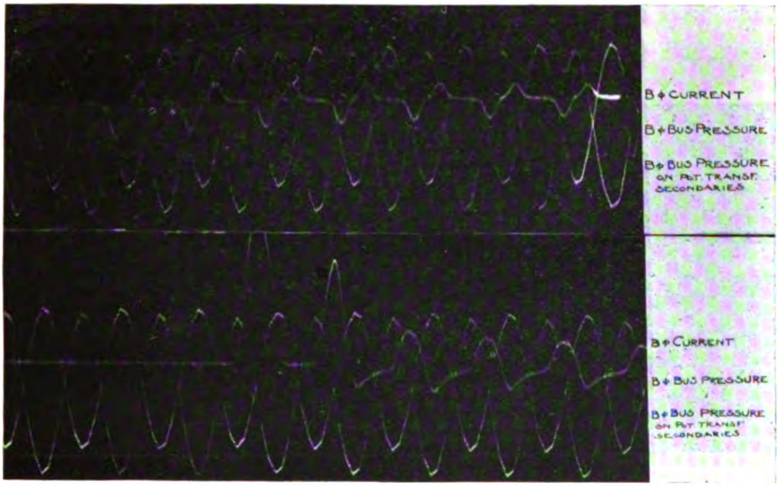


FIG. 11.

If we interpret the discussions of American cable engineers aright, they concur with Mr. Apt in his prophecy regarding single-conductor cable. The heating of the dielectric due to electrostatic stress with consequent weakening of insulation, the critical voltage which no practical thickness of insulation will withstand—these and other conditions limit the stress to which insulation can safely be subjected. With single-conductor cable in a three-phase system the line pressure can thus be $\sqrt{3}$ times the maximum safe cable pressure. A thin wall of high dielectric strength is desirable to lessen heating and to keep the cable from being too large and too stiff, but then the corona effect due to highly concentrated electrostatic stress must be considered and guarded against. Asphaltum troughs certainly guard against electrolysis and also insulate the lead sheaths of adjacent cables from each other. These sheaths should of course be grounded at one end. It is possible that the commercial demand for underground cables at voltages from 30,000 to 40,000 will result in the use of single conductor cable possibly embedded in asphaltum.

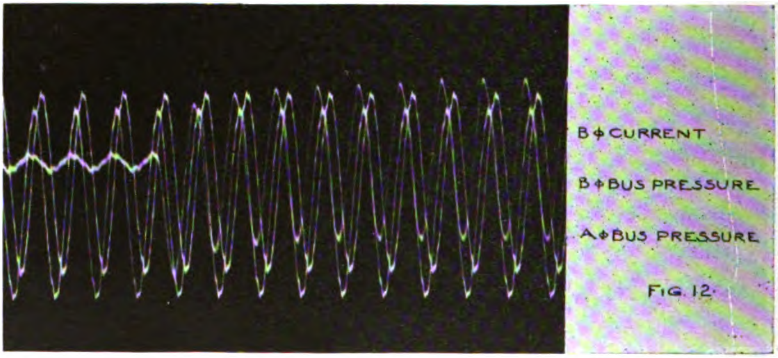


FIG. 12.

With the increasing popularity of all-the-year country life and with the spread of communities as mentioned in the beginning of this paper, it is not hard to imagine a time when it may in exceptional cases be desirable to put some cross-country lines or parts thereof under cover. The general dependance on electrical energy and the immense investments at each end of these transmissions may in special cases justify a fairly large expenditure, provided a very reasonable assurance for reliability is obtained. As many of these lines will be operating at pressures beyond the reach of underground cables, it is possible that a recently suggested protected bus-bar construction may be used. Such a construction could follow the general surface of the land and be built on a right-of-way in conjunction with a railway. The art of insulator manufacture will undoubtedly advance so that pressures of 200,000 volts or more could be employed if conditions should ever demand such pressures. This construction appears to obviate many of the shortcomings of present high-tension cable systems.

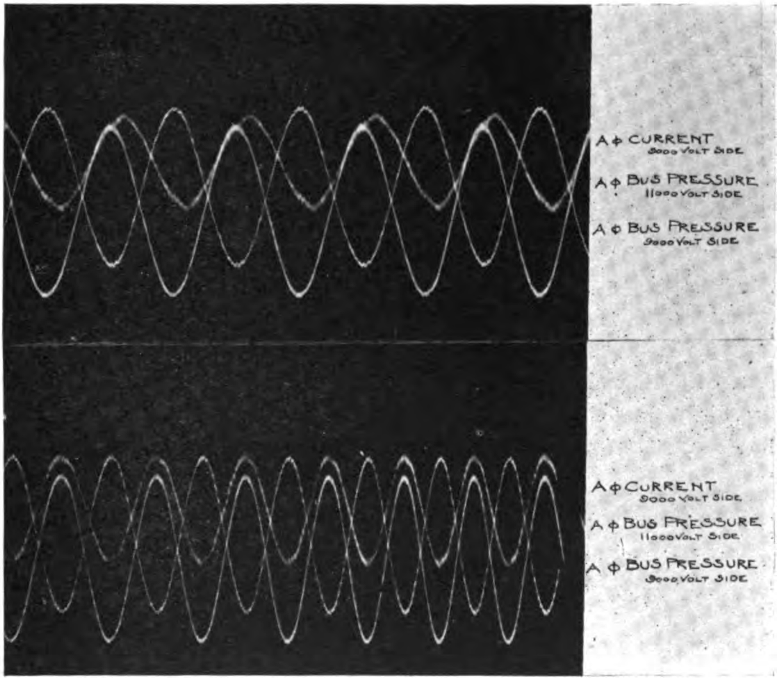


Fig. 13.

Summary

From the viewpoint of the investor or operator the state of the art regarding high-tension underground transmission might be summarized as follows:

1. Underground cable systems of 11,000 volts and under, if properly made, installed, and operated, will give at least equally and probably more reliable service than most of the other elements in the electric power system of which the cable system is a part.

2. Where local and commercial conditions justify, pressures as high as 25,000 volts can be satisfactorily used even for systems aggregating as much as a hundred miles of cable. No single line of such a system would be much longer than twenty miles. If higher voltages are needed to meet operating requirements, and can be justified commercially, special construction will be necessary to overcome limitations in paper, rubber, or varnished cambric insulation, and also in the standard forms of underground conduit or subways used in this country.

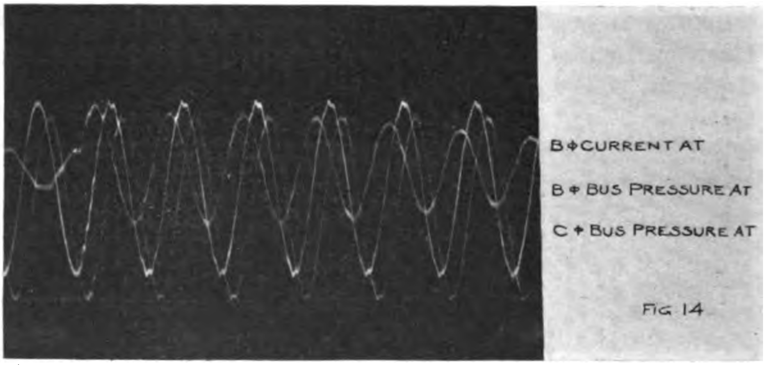


FIG. 14.

3. On comparatively short lengths, underground or under water, as a part of a long overhead transmission line, cables operating at 40,000 volts can be used.

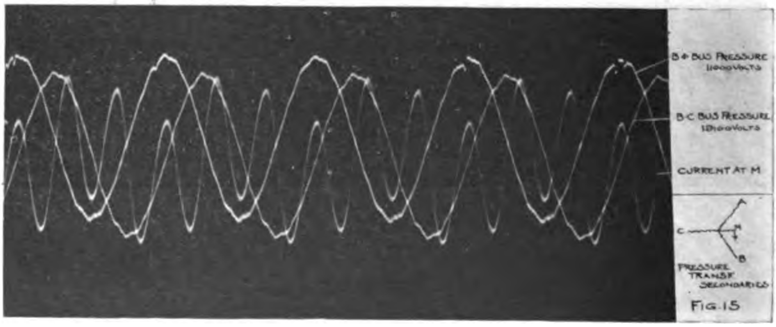


FIG. 15.

4. Potential rises of 50% and 100% are not uncommon in large underground cable systems, although this fact may not always be manifest, due to high factor-of-safety.

5. Definite knowledge of what actually occurs in large high-potential underground systems is still meager, especially regarding intensity and frequency of surges, heating effects, and critical temperature for various kinds and thickness of insulation, corona effects, and similar matters.

In conclusion we would urge all companies having high-potential cable systems to keep a complete and systematic record of all troubles. To quote Dr. Steinmetz:

> To determine the origin and cause of high voltage disturbances, so as to be able to guard against their recurrence, the most important thing seems to be to very carefully observe and record all the details of the phenomena, even those which appear unessential. The existence of static on switchboards, lines, etc., and the existence of voltages and currents different from those which may be expected, require special attention. Either of these is sufficient to raise the suspicion of some dangerous fault in the system or some dangerous arrangement of apparatus, which requires consideration . . . The severity of the phenomena depends almost entirely upon the power momentarily available in the system and very rapidly increases with the size of the generating stations. With the increasing power and extension of electric systems we must expect to see these disturbances increase in destructiveness. The prospect which this holds out for the future is not very agreeable; it shows, however, the increasing importance for the operating engineer to study and become familiar with the subject, so as to be able to cope with the problems which are before him, which perhaps are the most serious in the field of electrical engineering . . . It would therefore be a great help if a far closer interchange of experience existed between different operating Engineers.

May we not urge on all engineers to remember these words and to appreciate how by following Dr. Steinmetz's bidding we all can help to advance the art.

ADDENDUM

Spark-gaps. In using spark-gaps as a means for measuring potentials, certain precautions must be taken to insure reliable results. This fact is, of course, well known. The spark-gaps mentioned in the paper were made up on the usual insulated standard and provided with ordinary No. 5 sewing needles. The series resistance consisted of carbon rods, of an amount to limit the current to about one-half ampere at normal pressure. In order to get the correct interpretation for the various settings, the conditions of humidity and temperature of the places where the spark-gaps were installed were duplicated in the laboratory and the gaps were repeatedly calibrated from 0.4 to 1.3 in. gap.

Within this range they were found to agree to within about 2%. of the Institute Standardization Rules. It is safe to assume then that the indications recorded in the paper are correct within 5%, which is well within the accuracy required for this work.

Where the spark-gaps are in continuous service, to detect occasional high rises it is necessary either to renew the needles daily or to brush the points frequently to avoid an accumulation of dust which would alter the effective gap-distances. Any tight enclosure around the gap to prevent this accumulation would introduce errors due to the ionization of the enclosed air. During a discharge the needle points burn to a bead, the size of this bead being an index of the severity of the discharge, and thus roughly of the intensity of the disturbance at that point. A recording meter is placed in series with the gaps to record the time of the discharge.

Oscillograph. The development of a successful portable oscillograph marked an important step in the development of cable systems. It afforded a means for studying the system analytically, so that causes for possible unstable conditions could be determined and guarded against. In the particular application of detecting voltage rises of short duration its usefulness, while still very great, is more limited. The time-interval, already mentioned in the paper, introduces an external limitation. The limitations of the apparatus itself are principally as follows:

1. The free periodicity of the vibrators is less than that of some occasional waves of very short length. In the oscillograph used in the test the vibrators were adjusted for their highest free periodicity, about 6,000 cycles per second. Any peak having a periodicity higher than this would not be correctly recorded. However, a peak of such extremely short duration would have too little energy to cause a harmful disturbance and would thus be of little interest.

2. The vibrator cannot be made absolutely dead-beat, but fair results are obtained with five parts of castor oil, and one part of turpentine as the damping medium.

3. The self-induction of the vibrator circuit is not entirely nil, but is sufficiently low to be practically negligible.

4. The sensitiveness of apparatus cannot be made perfect, and its degree of perfection in this regard determines the degree of accuracy of its indications. The amperes per millimeter of deflection of the three vibrators used is from 0.00518 to 0.00578.

While in these four important qualities the oscillograph does not attain the ideal, yet for all practical purposes the apparatus is quite satisfactory. The limited time-interval of application is the most serious shortcoming, and probably the cause for the absence of double-potential peaks on the curves. A great number of oscillograms could be taken and yet none of them happens to coincide in time with a high peak. This was actually the case in the tests made, during which there was never a spark-gap discharge simultaneous with the taking of an oscillogram.

DISCUSSION ON "ELECTRICITY AS VIEWED BY THE INSURANCE ENGINEER. SHOULD THE A.I.E.E. INTEREST ITSELF IN FIRE PROTECTION?" ATLANTIC CITY, N. J., JUNE 29, 1908

(Subject to final revision for the Transactions.)

Chas. P. Steinmetz: The matter of fire protection is of extreme importance, and the Institute should certainly actively coöperate with other organizations in the effort to reduce the risk. I believe, however, the question is a far broader one than that of fire hazard. Electrical fire hazard may be of interest to the fire underwriters, but it is equally important that the Institute should consider the danger of electric power to human life, to invested capital, to the destruction of apparatus, etc., even if the destruction does not mean an increased fire hazard. The Institute is the one body which could take up this subject in its broader aspect. I think that the Institute should appoint a committee dealing with such questions. Such a committee may better existing conditions by establishing rules. A safer and better way for the committee to act would perhaps be to obtain papers that reflect good engineering practice, calling these papers to the attention of the public at large. This would be more effective than the formulating of a lot of rules. These papers could discuss the practice of carrying extra high voltage lines through towns and cities and indicate good practice in overhead lines of different voltages, and whether these overhead lines of different voltages should be on the same poles or not. Rigid rules on all these matters cannot be insisted upon, but in a paper an author can readily state his views and thereby bring the matter before the whole Institute for discussion.

DISCUSSION ON "THE MEASUREMENTS OF ROTARY SPEED OF DYNAMO MACHINES BY THE STROBOSCOPIC FORK."

ATLANTIC CITY, N. J., JUNE 29, 1908

(Subject to final revision for the Transactions.)

J. B. Taylor: The stroboscopic disc illuminated by an alternating-current arc or incandescent lamp has been used for a number of years to determine the speed of induction motors, synchronous machinery, and of other pieces of apparatus. This method of obtaining intermittent illumination is much simpler than by means of the fork described in this paper, and for some purposes gives the desired information with greater accuracy.

The distinction between the two methods is that the fork gives very accurate speed determinations, while the illumination by an alternating-current source of light gives even more accurate *relative* speeds of apparatus and frequency of alternating current system. In operating and testing alternating-current machinery the electrical engineer is more often interested in the relative speeds of generator and motor than in the exact determination of speed referred to the clock. For example, in testing an induction motor it may be desirable to know whether the slip under a given load is say 2 or 2.1%, while it is immaterial to know whether the motor is actually running at say 1800 or 1795 rev. per min. For this test the alternating-current illumination gives the slip directly, while the fork would require simultaneous observations on motor, and on generator or synchronous motor.

When studying pulsation of synchronous machinery or angular lag of synchronous motors, synchronous converters, etc., with variable loads, excitations, and reactances in circuit, the alternating-current arc is again superior to the stroboscopic fork; for while the fork can give general indications of pulsation, it can give no indication of the angular lag referred to.

I have found these stroboscopic discs useful in another way not mentioned in the paper—in the determination of the speed of very light pieces of apparatus which have insufficient power to drive speed indicators or tachometers. For this or any work where actual speed rather than relative speed is desired the fork will be found useful, and I think that the authors of this paper should be thanked for having brought it to such compact and convenient form.

C. A. Perkins: I have been doing some work with the stroboscopic fork, and any one who will try it in the laboratory will be interested to find how it smooths out characteristic curves, or any curves depending on frequency, to have an accurate device for determining the speed.

I wish to call attention to the range of speed obtained without having any shifting device. Use a tuning fork making thirty vibrations a second, or 1800 per minute, and the speeds given in the first column will be obtained. A fork which makes twenty-five vibrations instead of thirty gives the speeds in the second column, while a fork with twenty vibrations gives the speeds in the third column.

Vibrations	30	25	20
full-speed	1800	1500	1200
one-half	900	750	600
one-third	600	500	400
one-fourth	450	375	300
one-sixth	300	250	200

The first fork gives, without any slider, all the speeds called for in 60-cycle, alternating-current machines.

The method that I have used for observing synchronism is different from that described by Dr. Kennelly, and was suggested to me by the device which I mentioned at the Asheville meeting, for measuring the slip of motors, by means of a disc on the shaft, with a hole or slit in the disc. If such a disc, provided with a single hole, is placed on the end of the shaft of the machine whose speed is to be measured, and if the experimenter stands so that he looks through this hole at the fork, he will have one look at the fork at each revolution. Suppose the shaft to be rotating at a speed of 1800, then the two are in exact synchronism, and the fork will seem to stand still. Now if the motor speeds up five revolutions per minute, he will see the fork apparently make five vibrations per minute. Instead of adjusting the fork, the experimenter counts the apparent vibrations of the fork. They can be counted up to 150 vibrations per minute, so that the one running at 1800 vibrations can be used for all speeds between 1650 and 1950, the one running at 1500, from 1650 down to 1350, and so on. Therefore, without any slider it is possible to use three tuning forks for all speeds in ordinary testing work. At the higher speeds, one hole in the disc is sufficient, but at the lower speeds the fork is seen at such long intervals that it seems to flicker, and it will be necessary to have two or three slots, according to the speed which is to be used. I have used this fork especially for alternating-current work; it is a simple, satisfactory, and inexpensive apparatus for this purpose.

C. H. Sharp: I think most of us are more or less familiar with the various applications of the stroboscopic method to speed measurement, but I wish to express my sense of our indebtedness to Dr. Kennelly and Mr. Whiting for having reduced this method to such a practical and convenient form for actual use.

It is not difficult in a well equipped laboratory to assemble a combination of tuning forks and rotating discs, or something of that kind, and make it work nicely there, but here is a thing that can be picked up and taken to any place where a test is to be performed, where we merely attach a disc to the rotating element and measure the speed accurately, or measure the slip or variation of speed accurately.

A. E. Kennelly (by letter): It has been found that no target is ordinarily required when the fork is used to measure the speed of alternating-current machines for 60-cycle frequency. It suffices with such machines to illumine the polar projections of the rotor, and examine these through the fork, in order to measure their speed, unless the speed and frequency should be more than 5% in error.

DISCUSSION ON "WATER POWER DEVELOPMENT IN THE NATIONAL FORESTS. A SUGGESTED GOVERNMENT POLICY."

ATLANTIC CITY, N. J., JUNE 29, 1908

(Subject to final revision for the Transactions.)

J. H. Finney: Mr. Baum's paper is an interesting presentation of his views as a "power enthusiast and a believer in a cheap source of power," and his belief that "cheap power is vital and necessary to the present and future development of the country" will be, I am sure, supported heartily in this assemblage. We may also be classed as power enthusiasts. I think, however, that his presentation of the case is wrong from several standpoints:

1. In considering the national forests, wherever located, in the light of a local asset and not as a national asset, in which all the people should share.
2. In basing a power charge or franchise solely on the cost of forest conservation and not on the value of the grant fixed by the earning capacity.
3. In the attitude that assumes that a policy other than that outlined by him would put a tax on discovery, invention, and development, by ascribing to capital and genius, seeking legitimate investment and fair returns, attributes that indicate a selfishness fortunately not always true.
4. By a disregard of what might be termed the "rights of the people" in and to an asset of perpetual value, national and not local in character, a value that increases from decade to decade, as coal becomes scarcer and dearer.

Let us first see what the government's stand is on the question of charges. It can best be stated in a general way by quoting President Roosevelt's specific statement before the recent Conference in Washington.

> My position has been simply that where a privilege, which may be of untold value in the future to the private individual granted it, is asked from the federal government, that the federal government shall put on the grant a condition that it shall not be a grant in perpetuity. Make it long enough so that the corporation shall have an ample material reward. The corporation deserves it. Give an ample reward to the captain of industry, but not an indeterminate reward. Put in a provision that will enable our children at the end of a certain specified period to say what in their judgment should be done with that great natural power, which is of use to the grantee only because the people as a whole allow him to use it. It is eminently right that he should be allowed to make ample profit from his development of it, but make him pay something for the privilege and make the grant for a fixed period, so that when the conditions change, as in all probability they will change, our children, the nation of the future, shall have the right to determine the conditions upon which the privilege shall then be enjoyed.
>
> Where that policy can best be carried out by the state, carry it out by the state; where it can be best carried out by the nation, carry it out by the nation. My concern is not with the academic side of the question; my concern is in the employment either of the principle of states rights, or the principle of national sovereignty, as will best conserve the needs of the people as a whole.

This is a clear statement of a just and righteous intent, and who among us will question its honesty or the wisdom and desirability of its proper and successful accomplishment? This policy has, I believe, been more specifically elaborated by the forest service in certain cases, involving governmental grants as a definite policy, namely:

(*a*). The charge for power permits should be based on the power value of the land occupied and the value of the services rendered by the government.

(*b*). The proceeds from any particular permit may legally be appropriated by the Congress for any public purpose, and, under the same policy, may properly be used for the expense of administering in national forests or for the reclamation fund or for the proposed inland waterways fund.

(*c*). The plan of calculating the maximum conservation charge upon the yearly cost of forest conservation to the government would be impracticable, for the additional reason that such cost ought to be vastly higher than it is now. In the European forests the cost is several dollars per acre as against one cent per acre this year in this country.

(*d*). The question of the charge for power plants is a unit. In considering it, the rental value of the land and the value of the services rendered by the government in forest conservation should and must be considered together.

(*e*). The rental value for power purposes of the lands occupied should be paid by the permittee, not merely their value for forest purposes, farm purposes, and the like. The government is entitled to their value for all purposes, especially including the purpose for which they are actually occupied. This value must be fixed by the administrative officers of the government at such a rate as will encourage the taking of permits. But the government should retain permanent ownership, subject to the temporary right of the permittee to use the land.

(*f*). Practical considerations of administration make it desirable that the charge for power plants should be uniform. It has therefore been fixed at a rate which is believed to be sufficiently low not to check the development of any project.

While this policy may not be yet fully worked out, perhaps may not be the final word, it is, I maintain, in exact accord with the views and policy which the President seeks to establish, which in its final analysis is simply equal justice to both grantee and grantor, in rights which involve the use of the common property of the people as a whole, rights which are in their strictest sense, ours only as trustees and guardians for the future.

It may not be amiss to say here that this idea of trusteeship, while not strictly new, has in the past few years attained a new significance; and there are evidences of an awakening of the public conscience in respect to our guardianship and to our obvious duty to ourselves and to posterity in these matters that betokens a better America. The whole conservation movement, crystallized by the notable conference just held at Washington, marks, I believe, a new era in American thought and American habit.

Forests as a national asset. The national forest in the West is the heritage of the whole people. No state or local boundaries were in the mind of the Almighty when the forests were first planted by him. No state boundary now confines their use or benefits or value to the state alone. The California forests serve other states in water conservation, in water power, in climatic effects, in supplying timber, grazing, etc., and the same is true of forests whether located in Wyoming or Washington or Idaho. They are public domain, belonging to the nation, not to the states containing them. They are, therefore, in all the benefits and profits accruing from them, the common property of the nation. The state fortunately containing them gains the greatest benefit, and rightly so, but no claim that they are the exclusive property of the state as regards benefits or profits is tenable. The nation is the sovereign, and as a matter of fact and right the profits from them, while in part shared with the state, are converted into the national treasury. They should be turned into a forest fund that could be used to establish other national forests.

In the east where the Appalachian national forest is projected, and so badly needed, the situation is different only in degree. The states agree to relinquish sovereignty, the title passing by purchase to the new owner, the federal government. The states will get their share of profit—the balance goes into the treasury. Nor can the forest here be considered a local asset. The states are manifestly unable to act effectively in its establishment. The very fact that the national government must act shows its interstate, its national character.

From the forested mountains of North Carolina flow streams that make power and navigation possible in streams in adjacent states—north, south, east and west. Some twenty states are directly, and the whole nation indirectly affected by what North Carolina does, should she denude or preserve her forests. It cannot be considered, therefore, as a local question, and I think Mr. Baum's view is narrow and untenable. Does the San Francisco post office expend its surplus only on San Francisco's postal service, or the New York post office on New York's? Is not the profit from these larger and more prosperous centers used to improve the efficiency and value of the postal service as a whole to the whole people?

Let us look into this a moment. The government at present sells the timber on the basis of its selling value, because the timber costs have been to the present time practically nothing, except the small value of the land set aside, and the maintenance and patroling and similar charges. We have not begun to spend on our forests the amount of money which they should have yearly for a definite reforestation policy. Will Mr. Baum advocate this charge against the power company, should we spend as we some day must, large sums for reforestation?

The national forest, so far as the timber is concerned, was operated at a loss last year. Other forest products considered, there was a substantial profit, and this profit is increasing year by year and rightly so. They become without impropriety a profitable investment to the government, without imposing any purposely designed hardship on the grazer or lumberman or miner or homesteader. If the government has instead of grazing privileges, or lumber, a water power to dispose of, in what respect does it differ from the other forest products? Is not its value what it is worth to the grantee, whether it be five thousand or fifty thousand kilowatts, and is not this value fixed solely by what it may be able to earn as a return on the investment? The 5000-kw. plant may be just as able to earn a fair return as the 50,000-kw. plant. The promoter or the developer might prefer the larger plant, perhaps, as offering more chance for profit, just as a street railway in New York might be a more attractive enterprise than one in Atlantic City, and yet both New York and Atlantic City have street railways, and it is barely possible that the smaller one is the more attractive investment.

It is largely a commercial problem. The 50,000-kw. plant would not be developed if no profitable market existed, even if there were no charges imposed by the government. Commercial considerations govern. There are plants operating and making money where fixed charges are abnormally high, costing $200 or so per kilowatt installed, and selling power at a low price, too; there are others that have cost $80 or less per kilowatt installed that are selling power at a higher rate than the other plant. They all fix what is claimed to be a reasonable charge for current, under the conditions existing in their particular field, and this charge varies quite as much and as radically as the installation costs. It is a reasonable charge at one cent per kilowatt-hour, or two or more, depending on local conditions. We cannot well object to a metered tax on production when we are at the same time through our public service companies, such as the power company, the telephone company, the gas company, and the water company, strenuously and persistently advocating a metered charge for consumption. It is not possible to impose an equitable tax in any other way.

The plant that has so narrow a margin between success and failure as would be seriously affected by the imposition of a fair tax, whether this tax be 1/1000 cent, or 1/100 cent per kilowatt-hour, or even more, perhaps, has small prospect of attracting investors. It is not at all impossible or difficult—we are doing it every day—to get at exact figures of development costs in any project contemplated, and accurately to estimate its earning capacity. We are doing the latter, too, every day. One needs only to recall the engineering reports of the past and the present to see that it is done on the basis of "what the traffic will stand," nor is there impropriety involved in this. When this is done and the property cannot stand a reasonable tax on its output, that project is not a commercial one at the present time, and under present conditions and must await development, as does many another, until a more favorable season.

A tax on discovery and invention. There are no inherited or inherent rights in capital privately to exploit our remaining resources in mines and lands and forests, although this statement seems unduly optimistic in the light of past history. The Americans are over-patient and have been over-exploited, to put it mildly. There may be no power monopoly contemplated, though a water power company is by nature a monopoly *per se.* It is many times the only possible source of supply of a given market. The opportunity for monopoly unquestionably exists in many places now, and there are some striking examples of what might happen to water power in what has happened in the past in some notable combinations of certain railway and other large interests that can be readily recalled.

The government imposes a tax to-day on inventive genius by charging for a patent—the child of one's brain—a uniform charge regardless of the cost of maintenance of a patent office. It fixes also a limitation of the grant to seventeen years—but the Patent Office is full.

No fears are justified, however, that the imposition of a tax, which would net him forty-nine per cent. instead of fifty per cent., or five and nine-tenths instead of six per cent. on a solid investment, will curb either the American's ingenuity or his inventive genius, or his discovery of the quickest way to get the forty-nine per cent. or five and nine-tenths per cent., if he cannot have the larger returns.

Disregard of the people's rights. The real ownership of these natural assets in mines and forests and soil and water clearly lies in the people as a whole—a part of the nation's heritage, whether natural or artificially created through governmental agencies. Some profit therefrom belongs to the people, just as clearly and on the same broad ground as that some profit belongs to the capital and brains developing them. With this right of the people to profit, there exists and there is imposed the duty to fix reasonable restrictions on their use. Rights to exploit them properly should be granted on the basis of a definite term of years for the franchise; a definite basis of fair charge on the output; fair regulation by the government—a policy that is embraced in what is termed "a square deal" to all concerned; to the investor, to the corporation, to the power user and to the nation, and, incidentally, to posterity.

As engineers, knowing better, perhaps, than any other class of observers the immense potential value represented by forty trillion cubic feet flowing annually within our borders, descending an average of twenty-five hundred feet to the sea, and what it means to present America and its future value to future America; dimly realizing the infinitely greater value and incalculable good of our waters in the light of the new concept of them in their substance, or corpus, we cannot go on record as indorsing any plan involving their exploitation and use, that does not have strictly in mind, not only their fullest development and conservation in the largest sense for power, for soil, for water supply, for the health and very life of the people, but the plan must be one that will do equal justice to all and contain special privileges to none.

No less an authority than Jefferson declared that " the earth belongs in usufruct to the generation at any time living upon it." This view is as true to-day and as free from demagogy or socialism as when uttered. It is plain common sense and common honesty, and we as a people are at last beginning to realize it.

E. R. Taylor: I would like to see Mr. Baum's paper broadened out, and my criticism is mostly upon paragraph B, in which Mr. Baum says:

> The proceeds from any particular privilege cannot be devoted to any other watershed or any other section, or for any purpose except the particular privilege.

I had the honor to read a paper on " Forestry, Water Storage, Power and Navigation " before the American Electrochemical Society a few weeks ago. In that paper I think I advocated the converse of that advocated by Mr. Baum in paragraph B. I said there:

> Let each state or section develop one or two streams completely with forest and lakes (and even farmers' tributary brooks to be paid back at cost) as illustrations, and put them to work earning money to develop others later. Let coöperation be the watchword. Private interests cannot do it as it ought to be done; public interests must do it, and the doing will be immensely profitable and a benefit for all coming time.

All of us realize the great value of these water power privileges, if they are rightly developed, and I suggest that all who are interested in the subject get a copy of the Third Annual Report of the New York State Water Supply Commission, which deals with this subject.

P. P. Wells: I desire to explain briefly the forest service policy with regard to what used to be called the conservation charge. I am not a trained engineer and must ask your indulgence on that side of the question. The service is very much indebted to Mr. Baum for the careful consideration he has given this subject. However, we agree with the conclusions that have been expressed by Mr. Finney.

Mr. Baum's paper does not clearly distinguish between the policy of congress and the policy of the service, the administration. Of course, to find out about the policy of congress we seek the statutes. In respect to the policy of the forest service as an administrative body I wish to say something about what its intentions are, what it has done, and what it would like to do.

In the first place, it does not like the present system of having permits for water power development revocable at the discretion of the secretary. That condition is imposed by the Act of Congress of February 15, 1901, in which it is expressly provided that they shall be revocable. The forest service would like to have authority to issue permits which would be irrevocable except for breach of conditions, for terms sufficiently long to guarantee security to the investor and a chance for full development.

At Mr. Pinchot's suggestion there was included in the Agricultural Appropriation Bill pending before the last session of Congress, a clause which would have given power to issue irrevocable permits for a term of fifty years. That clause, like all new legislation in appropriation bills, was subject to be stricken out upon a point of order raised by any one member of the House of Representatives. Two members made the point of order against this clause, and it was consequently stricken out.

As the law now stands, the service has gone as far as it can to give permanence. It cannot take away from the successor of the present Secretary of Agriculture the power to revoke the permit. It does, however, specify precisely before construction begins the maximum charge that is to be made in every case. This is fixed in every permit for a term of forty years, so that the service has gone as far as it possibly can to give certainty.

Secondly, for the reason explained so well by Mr. Finney, the service stands for the permanent government control of its great natural resources, and as each fifty-year license expires, new conditions may be then imposed in accordance with the changed circumstances that face the men of that time.

Thirdly, the policy of the service is that no permit which is issued shall be held unused. Pressure is put upon the permittee to make full use of his permit, first, by making a preliminary small acreage or mileage charge pending construction; secondly, by fixing in the permit a specific time in which construction must begin and another specific time in which it must be completed. That time will be extended at the discretion of the Forester, if unforeseen physical obstacles are met with.

Fourthly, the service stands for a uniform small charge or annual rental based on the amount of power developed. The justification of this charge, as Mr. Finney has explained, is that the title of the government to lands in the national forest is unquestioned and absolute. They belong to all the people of the nation. Whatever value there is in them belongs to all. If you consider this value, there are three elements in it, bearing on this matter, which we may call the resources, the land's resources and services rendered by the government. In these cases, with respect to water power, the "resources" of the forests may be taken to be the water alone, considered apart from the land itself. Our charge is not based on this element at all. The appropriation of water is made under the state laws. The second element is the value of the land as a power site. It is obvious that one piece of land may be very valuable for that purpose, and another piece of land less valuable, because either of advantageous reservoir sites for storage purposes, or because of a greater fall or head. The third element of value is the service of the government in maintaining a steady water flow by forest conservation. This last is the only element that Mr. Baum's paper considers.

In my opinion, Mr. Baum's analogies do not bear out his arguments. In the first place, it has been for many years the policy of the government to give free homes to settlers, and in furtherance of that policy the government irrigates arid lands at cost for homestead settlers. The present administration does not believe that that policy should be extended to large corporations, who use the public resources primarily for gain. So there is a broad distinction between the homesteader and the commercial user of natural resources that belong to the government.

Take the case of the mineral fuels. Two years ago the present administration definitely announced its policy as that of a lease system, rather than the present system of alienation of coal and oil lands in perpetuity. Take the case of railroad grants and free rights-of-way for railroads; that policy was initiated when the resources of the country were thought to be inexhaustible, and when the Pacific coast had to be connected with the East for political reasons. But the reasons for that policy no longer exist and they do not apply in the matter of water power. Take the case of timber. Timber is required by law, under Act of June 4, 1897, to be sold at public auction to the highest bidder without regard to the cost of administering the particular forest on which it is sold. Railroad ties, which Mr. Baum's paper mentions, could only be sold in this manner, without any reference whatever to the cost of forest conservation. Grazing fees on the forests are an attempt to approximate the grazing value of the land. So with mill sites; if a man wants a saw-mill site, as Mr. Baum mentions, we vary the charge precisely in accordance to the capacity of the mill. Thus all the analogies, except that of the homesteader, are against the position taken by Mr. Baum.

A word as to what Mr. Baum says about deductions from the charge on account of private ownership of land. It is a settled part of the policy of the forest service, that if a power plant occupies unreserved public land, over which the forest service has no jurisdiction (private land), a deduction will be made on that account, provided the patent by which the private land was acquired did not reserve to the United States a right-of-way for canals, etc., constructed under the authority of the United States. All patents for lands west of the one hundredth meridian, issued since the Act of 1890, do make such reservations.

Then as to water storage; the policy of the service is to encourage the conservation of water by storage, done by permittees, in such manner that they will not be charged for the conservation of the water they store. They will, however, be charged for the head which they get from the use of the forest lands, and which make this stored water valuable to them; in other words, there is a fifty per cent. reduction from the maximum charge on account of power produced by stored water which would not be produced by the natural flow.

In respect to what Mr. Baum says concerning the reward which should go to the enterprising discoverer of the best power sites; uniform charge is made, believed to be low enough not to obstruct development on any practicable site. It therefore leaves a wide margin of profit for the enterprising discoverer of a better site, and that margin is the wider as the site is the better.

A. H. Babcock: Paragraph B of Mr. Baum's paper has caused considerable discussion. It is my opinion that Mr. Baum had in mind the fact that in the case of a water power development, the power must be utilized within a limited area. The consumers in the area must pay the government charge; hence they are entitled to the benefit. The charge should be made as low as consistent with the development of that district. Mr. Finney's analogy to the post office charges being distributed for the benefit of the whole country does not seem to me to be a happy one, for the reason that a two-cent stamp must carry the letter into rural districts, and other places, where an adequate delivery system otherwise could not possibly be maintained.

President Stott: Some very important points have been raised in the paper and discussions, which I would hear brought out at greater length.

C. P. Steinmetz: I hardly need to say that I thoroughly agree with the opinion, that the preservation of our national resources is a most important problem requiring energetic and prompt action. I am sorry to say, however, that with regard to the methods proposed by Mr. Baum I must disagree in almost every particular. The first argument made by him is that the different water power developments should stand on their own merits; that is, that the proceeds from any particular privilege cannot be devoted to any other watershed, or any other section, or for any other purpose except the particular privilege. He contends that the development of the watershed should be considered as a private matter in that particular locality.

I do not agree with that suggestion, as I believe that, if followed out, it would defeat the very thing we are trying to bring about. It is the same argument which can be made, and is being made, against setting aside and preserving these national resources, that they are not of general, but only of local interest. It is of no benefit, it is claimed, to the Central States, to set aside the Appalachian reserve, or the White Mountain reserve, and therefore the Central States say they do not want the national government to which they contribute to pay for doing it.

That is Mr. Baum's argument, but I believe his argument is wrong, and there is a contradiction in the very statement which Mr. Baum has overlooked. He starts his paper by speaking of the preservation of the *national* resources, and then he says that these resources are only of *local* interest, and should be developed and paid for locally. If they are of local interest only, then they do not need the aid of the national government, but should leave it to local enterprise. Under such circumstances I should prefer to leave it to private enterprise. The only reason of calling for the national government is that the subject is not of mere *local* interest, but of *national* importance.

It may appear at first sight immaterial to California whether the water powers of Maine are developed or not, but if the failure to develop the water powers in Maine results in an increased consumption, say, of one hundred million tons of coal, the coal famine resulting will increase the cost of pig iron or structural steel to California as well as to Maine, and so one part of the country will suffer by the destruction of our national resources, by the waste of our national capital, equally with every other part. Hence it is not a *local*, but a *national* problem.

If the problem were merely to develop water powers, then indeed it is local; but the problem is much broader, it is the problem of preserving and protecting our national capital. Suppose for the sake of argument the cost of the development of the water power is charged to the individual location. Then there would be developed only those watersheds where the cost is lowest and the power greatest; that is to say, those cases where government aid is not needed, as private capital would sooner or later do the developing. But then the far more important problem would remain untouched; the problem where the watershed requires to be protected and would not be protected by private capital, because there is not enough power available in it to justify such protection. The destruction of timber and the erosion of hillsides at every rainfall would very soon be disastrous to the entire country. No effective protection or development can take place when this matter is considered as purely local. Such a policy would be very inefficient in carrying out our purpose of protecting and preserving the national resources, would indeed be the surest way of defeating this purpose. As long as it is a national problem, the nation stands or falls as a whole, is responsible as a whole, and has to take care of it or benefit by it as a whole.

Whether the payment for the work is made by the United States treasury, or by assessment on the beneficiaries of the development of the national resources, whichever it may be, remains for discussion, but certainly we cannot consider the development as a matter only of local importance.

Furthermore, it would be just as unfair to charge a high power cost to a moderate water power which may be very valuable and necessary, merely because the development of its watershed was rather expensive, while another water power may be developed almost free of charge where the watershed required very little attention. A part of the argument of the paper is that the proposed method of charge by the kilowatt output is unfair. Granting that, it should not be concluded that any other method proposed by the writer is therefore the proper method. If one proposed method is unfair, it does not prove the correctness of one other method; it merely means that we should find a fairer method than that which is proposed.

I agree with the writer that a fixed charge per kilowatt may not be fair. One thousand kilowatt of power developed near New York City is vastly more valuable than 5,000 kw. of power developed five hundred miles from nowhere. You may say we make the charge so low that every one needing the power can afford to pay the charge. That is unjust again, because we then fail to make a reasonable and fair charge on the profitable water power near New York City, and therefore fail to derive as much revenue for use in developing resources as the development of water power can stand.

The last point I desire to discuss is the feasibility of Mr. Baum's proposition, that the franchise privileges must be perpetual. He claims there is no franchise or privilege. But the matter is the same as if I buy a piece of land and build a private residence. In the same manner those which develop the water power should buy the land. He does not believe in this argument himself, however, because in other parts of the paper he uses the term " privilege " and so signifies that there is a little more involved than buying a plot of land for a private residence. However, whether we think it desirable or not, we must realize that there is a very strong and growing sentiment against perpetual franchises, against giving away national property in perpetuity, or even for a long term of years, such as ninety-nine years or fifty years. Whether this is desirable or not, we must realize that the sentiment is growing and will not reverse—and will have to be dealt with as a fact, whether we like it or not, so that it will be increasingly more difficult to get perpetual franchises or privileges, or even long term franchises. Whatever arrangements we so recommend, we will have to count on this condition—the lifetime of a franchise will be the lifetime of a generation, or something like twenty-five or thirty years at the most.

There are thus two features which we must keep in mind; to develop and protect as quickly and as completely as possible our national resources in forests and streams and mines, and to make the development such as to induce private capital to enter into it. The problem which we have to solve is how to combine the short-term franchise with such conditions, so that private capital will invest in these water powers.

Now to induce private capital to enter this field requires that capital must be guaranteed against confiscation, direct or indirect; that is, there must be a guarantee that at the termination of whatever franchise there is, there shall be no confiscation, that the value of the plant shall be preserved as a tangible asset of the investor. As soon as we guarantee that, I do not see that it matters very much whether the franchise is perpetual or whether it is relatively short. The only just objection against a short-term franchise is that the investor has to face the condition that he must get his full capital returned with interest within seventeen or twenty-five years, because he has no guarantee or protection of the investment beyond that time. The value of the investment must be guaranteed in any limited franchise.

There is however a franchise or monopoly very much stronger than any other franchise ever dreamed of by anybody, whether a water power franchise, or a city railway franchise, or anything else. The strongest indeed of all privileges, franchises, or monopolies is the manufacture of a patented invention. There is no restriction; you may develop the invention or not, you can give the public the benefit or not. You can throw it away, and no one has any right to object. You can charge ten thousand per cent. profit if you choose, but after a limited time, seventeen years, this monopoly expires. But there is no confiscation. Whatever factories, whatever plants you have erected to carry out this invention, they are still your property, except that now this invested capital has to compete on even terms with all other industries; that is, is entitled to a fair rate of interest, but no more fancy profits. So I believe some similar method could be developed for the similar problem of creating values, where values did not exist before, in the water powers, forests, and mines, and *unlimited* franchises for a limited time; that is, unlimited regarding restrictions, price, time of development, etc., might and should be given, because it is necessary to have the possibility of unlimited profit to compensate for the chances, which are not small, of complete loss in the failure of the power development. But that should be for a limited time only, say the same seventeen years the letters patent has to run, and after that time the franchise expires, and either the government can take over the plant at its actual value, or renew the franchise with such restrictions, limitations, or conditions, as may seem to it desirable, provided these conditions do not constitute a confiscation of invested capital.

I think this would take away the reasonable objections to the short-term franchise, and would make it feasible, by holding out chances of very large returns during the unlimited period, to take the risk of complete loss, because, after all, this idea of the water powers being very valuable is a misconception derived from looking at those powers which have been a commercial success, and forgetting to look at those many other franchises, city railways, etc., which have been developed and capital sunk into them without return, and many other similar properties in which large amounts of capital have been lost. The development of a water power is just like the exploitation of a letters patent, in the fact that the success of the two is a matter of some doubt—they are properties of questionable value—the water power may be, when fully developed, of extreme value, or it may be an entire loss. It is not an unquestionable asset, like United States bonds. If you desire to get the water powers developed, and desire to interest private capital therein, you thus cannot expect to limit the returns to the moderate values of the usual conservative commercial enterprises, because you cannot limit the chances of failure, and where there is a chance of loss you must compensate for it by the chance of more than normal gain or profit.

Wm. McClellan: I think we all agree that the word "national" strikes the keynote of this whole discussion. Those who realize the importance of this badly misunderstood question, and have taken the trouble to investigate the conditions, have found opinion is very likely to vary according to locality. In various parts of the West and South, great water powers exist more or less in their natural state. Whatever deficiencies or irregularities they have, are natural. When we come to the East, however, we find a large number of valuable water powers which may be called "spoiled water powers." This has occurred on account of the denudation of forests at the head waters. During this last winter I have had occasion to examine a number of these eastern water powers, many of them of comparatively low head. It is surprising to find how many places there are where not more than 500 h.p. can be developed at present, and yet records show that years ago, before natural conditions had been changed, there would have been at times as much as 5000 to 6000 h.p. Steps are being taken by several state commissions to determine plans and the cost for overcoming these deficiencies by making the flow of the river as uniform as possible throughout the year.

These great natural water powers of the West, needing in many cases comparatively little assistance, and the great spoiled water powers of the East, needing in some cases a large amount of assistance, all make up the heritage of the nation. The fallacy is very subtle, nevertheless it is an absolute fallacy, that these resources should be developed for the benefit of the immediate community or state. In the opinion of the speaker, these resources should be considered as a whole, and charges for development and assistance should be made in every case from the standpoint of general utility. The government, like an individual, should so manage its resources that all are brought up to as efficient a condition with as great earning capacity as possible.

It is for engineers to say whether a good water power is a real asset of the government, and is worth developing. They are best fitted to examine the local conditions in each case, and see what change is advisable for a water power.

It is safe to say also that if this matter is not taken up on a national basis, there will be difficulties later, inasmuch as a large part of the water power of the country exists at present in locations which come under the national government, and in many other cases, where strictly speaking it is a state matter, attempts will be made to transmit power between the states. This will probably become a matter for national control some time later.

C. H. Porter (by letter): It seems to me that every one who considers this question must agree with Mr. Baum that the regulations of the government with reference to the granting of power permits in national forests should be such as to encourage the development of water powers and that the present regulations are unsatisfactory. That the Forest Service recognizes this is shown by the following extract from a letter signed by Mr. Pinchot, and dated May 5, 1908:

> I wish to say now that I have never advocated revocable permits. The Act of February 15, 1901, expressly requires that all permits shall be revocable. I have consistently advocated legislation to authorize the issue of permits for a fixed term, which should be sufficiently long to give reasonable security to investors—say fifty years. During this term the permittee, so long as he fulfils the conditions expressed in his permit, should be as independent as the holder of any other property. Moreover, the conditions of the permit should define with as great accuracy as possible the maximum burden placed upon him. He would then be in a position to collect investments in his enterprise by offering certainty and security to the investor.
>
> For these reasons I secured the insertion by the House Committee on Agriculture in the agricultural appropriation bill, now pending, of a clause authorizing the issue of irrevocable permits for fifty years. This clause was stricken out in the House. I believe that it would have been enacted into law if it had received the support of the friends of the power companies and that the companies have themselves only to blame if they are now suffering from the fact that permits are now revocable.
>
> A conference between representatives of the government and representatives of the power companies and of banking houses interested in financing power projects was held in Washington in February and March. The government opened the conference by proposing legislation of the character above indicated. The companies were unwilling to accept that unless they also got much more. The administration cannot therefore be held responsible for the fact that this legislation has not been secured.

The real question under discussion, then, is whether the government should grant very valuable privileges to the power companies upon conditions more favorable to the latter than are necessary to insure the development of water powers. The power companies are justly entitled to a rate of interest on their investment proportional to the initiative required and risk involved and one which will make the proposition attractive to capital, but why are they entitled to anything more?

It is stated in the paper that the reserves or national forests were created primarily for use and not for profit, but if there be profit involved in the administration of the reserves why should it not go to the government representing the public rather than be handed over to a few corporations? The fact that the government has in the past practically given away for private exploitation by far the greater part of the natural resources of this country is not, it seems to me, an argument for giving away the small remnant the legal title to which still remains with the government.

If the granting of permits for 50 years, irrevocable except for breach of conditions, will result in the development of water powers with its many obvious concomitant benefits, what is to be gained by the granting of permits in perpetuity except the enrichment of a few individuals? If there is any question as to whether 50 years is a sufficiently long period to induce the desired result, it would seem to be a reasonable method of ascertaining the facts for the government to offer to grant permits for this length of time and then, if permits are not applied for, the granting of permits for a longer period can be authorized. In any case the government should retain permanent control of all water power resources now in its hands, and issue permits for development under conditions fixed for a definite period, at the end of which time the government should be free to make new stipulations and adjust the conditions to the circumstances then existing.

Mr. Baum raises the question of monopoly, and while a monopoly of the water resources of this entire country may, as he says, be absurd, a monopoly of the water powers of a given locality is certainly possible and in many cases probable. Even where there is not a monopoly of the sources of power there may be a monopoly, through exclusive franchises or otherwise, of the power market practically available in a given district. Whatever the cause, the resident of a city in California confronted with a local power monopoly will derive no advantage from the fact that Niagara power, for example, is controlled by entirely independent financial interests.

In the paper it is stated that the profits of a national forest in California should not be used to maintain a reserve in Maine, but the proceeds from the sale of the public land included in the national forest would, if the reserve had not been created, have been turned into the national treasury, not turned over to the state of California, and why should not the same course be followed with any profits which may arise from the administration of the reserve? Both before and after the creation of the reserve the land belonged and belongs to the nation.

It is true that settlers in the vicinity of a reserve should be given first consideration in the disposition of the products of the reserve, but in general water powers are not developed on a coöperative basis by the people who use the power but by bondholders and stockholders at a distance. The price of power will always be determined by the cost of competitive power or by the price at which, with the corresponding amount of business, the profits will be a maximum, not by the actual cost to the company of the power sold the consumer. The amount of the government charge affects the last item only, but the two determining factors are entirely independent of it.

Furthermore, while it is the policy of the government that settlers in the neighborhood of any one forest be preferred to people at a distance, so far as the right to use the land and resources of the forest is concerned, it is also its policy that,

> They should pay a fair price for all exclusive commercial privileges which they get. In other words, they should not be preferred to others as to price but should be preferred to others at the same price. This is the rule in the case of grazing permits, which are further restricted to prevent monopoly by large owners.

Whether it is "only fair that the government charge against the power privileges should be based on what the government furnishes" depends upon whether the cost or the value of what the government furnishes is meant. As an analogy the case of railroad ties is mentioned, and it is claimed that the value of these should be calculated on the yearly expense of maintenance and the number of ties the reserve can produce annually. As I understand the meaning of the word "value" it is the amount of money for which a thing can be sold. As a matter of fact, in disposing of any of the timber products of a reserve it is the market value, determined by sale at public auction after advertisement, not the cost of maintaining the reserve, which fixes the price at which the timber is sold. An exception is made in the case of the small homesteader in the immediate vicinity of the reserve who is given free certain forest privileges for personal and non-commercial use. Thus he can have without charge a small amount of timber, $20.00 stumpage annually, and is allowed to graze free six milk or work animals. When the timber is sold to a railroad or lumber company, the government receives the market price of that kind and grade of lumber. It would, it seems to me, be absurd for the government, representing the public, to sell timber from national forests to lumber companies for a nominal sum in order that the lumber companies might make an excessive profit in reselling it to the public.

While the charges of the government to the power companies should not be excessive and should not exceed a definite maximum set in advance in order that the fixed charges on a development may be accurately foreseen, nevertheless I see no reason why the value of the power privilege rather than the cost of maintaining a given reserve should not be taken account of. in determining the government charges just as the market value of the timber is considered in fixing its price.

The value of the land for power purposes is approximately measured by the amount of power actually developed each year. It is also an inverse function of the cost of development per kilowatt and the distance from a market, but the obvious practical difficulties in the way of taking account of these and similar factors are such as to leave the amount of power developed as the only practicable basis upon which to evaluate the power privilege. Mr. Baum says very justly that the power man who discovers a better power development than another man should have the benefit of his enterprise, and it would therefore seem to be fair that the man who discovers a power having a low development cost per kilowatt, or one near a market should pay a less percentage of his profits to the government, as he would with a uniform charge, than a man who can only find a power which must be developed at high initial cost or which is three hundred miles from a market.

As Mr. Pinchot says:

> Any private land owner having a power site on his land would refuse to rent it for its value considered as a wood lot, but would insist on its power value as the basis of the annual rent. If his property were to be taken from him for power purposes by condemnation he would be entitled to its value for such purposes.

The principle involved has been affirmed by the Supreme Court of the United States. Why should the fact that the renter in the case we are considering happens to be the national government make any difference? The power privilege is worth just as much to the power company whether it is secured from a private individual or from the government.

To summarize the difference between Mr. Baum's point of view and my own: he believes that water power development should be encouraged as much as possible; I believe that it should be encouraged only so much as is necessary to insure development. Beyond this the interests of the public not these of the water power companies should determine the government's policy.

J. A. Britton (by letter): I believe that the United States should grant to all bona fide hydroelectric corporations permanent rights-of-way and grants of government land without any tax whatever being made therefor, other than the cost of the land, fixed by the government on the same basis as valuation is fixed for homesteaders. Such rights, when granted, to become permanent only upon the expenditure of a sum of money representing four or five times the value of the land, and to provide therefor that upon cessation of use for a period of one year, except in case of unavoidable accident or destruction by elements of the improvements, the grant should revert to the United States.

The protection of a watershed should be a matter within the province of the United States, without imposing any tax upon the users of the land. The resultant benefits gained by the United States and the several states in which these patents would be used, and the taxes derived therefrom, being, in my opinion, sufficient to warrant the government in taking care of and protecting watersheds utilized, as such care and protection results as much to the benefit of the entire community through which the streams may flow, as it does to the company utilizing the water for power purposes. I am unalterably opposed to the levying of any tax by the state, or by the United States, where forest reserves are concerned, against enterprises of this character. To subject an investment of this kind to the whims of the legislature of any state and the Congress of the United States would be to invite confiscation of property, and would result in eventually paternalizing, and would, if neither of the above occurred, bankrupt any corporation, as it has no redress, nor can it in California now, nor will it hereafter, be permitted to increase its rates, due to the trend of the present legislation in the matter of such close regulation of corporations. If any law is to be made, it should be a discriminatory one, choosing between the bona fide enterprises and those which are organized purely for the purpose of enriching the organizers.

I shall be very glad indeed to see a state or coast convention held to discuss this subject. I believe it very vital to the welfare of those who have, in good faith, invested their money in water power propositions in California and other states.

DISCUSSION ON " A STUDY OF MULTIOFFICE AUTOMATIC SWITCHBOARD TELEPHONE SYSTEMS." ATLANTIC CITY, N. J., JUNE 29, 1908.

(Subject to final revision for the Transactions.)

A. B. Smith: For a number of years it has been my hope that the automatic would be able to solve the telephone problem for large cities; that it would bring the rental a little lower for the benefit of the many who need the telephone but cannot now afford it, and that it would afford relief from the party line. That this can only be done by subdivision into small offices with short subscriber lines is acknowledged, but the apparently insurmountable obstacle of trunk lines and office expenses have stood squarely in the way. However, it may now safely be said that the automatic has arrived at that point of development where its claims merit serious consideration.

With regard to the claimed flexibility of the system in being able to use subscribers' lines for trunks, I ask if it would not seriously interfere with the practice of making trunk cables of lower resistance and electrostatic capacity than subscribers' cables? It would necessitate making the whole installation of cables good enough for trunks, which would be very expensive.

In a continuously growing city the telephones increase in number in two ways—increase of density and increase of territory. If merely the telephone density increased, and the transmission equivalents had been properly cared for, any district might be converted into a branch office and old subscriber lines used for trunk lines with no loss. But all around the edge of the city the telephone exchange is expanding and the length of lines increasing, so that to continue indefinitely with the process would eventually make transmission very poor. In this respect the automatic offers no additional advantages except as it makes profitable a smaller branch office.

In a multioffice automatic exchange the trunk repeater is used to relay the calls and permit each subscriber to draw talking current from the nearest battery. This introduces added complications into the selecting mechanism, but as far as talking is concerned a little comparison will show the conditions. In the common battery manual trunk circuit there are two repeating coils between the two subscribers, one in the cord circuit at the *A* board, the other in the trunk circuit at the *B* board.

No repeating coils are used in the automatic, their place being taken by the condenser-retardation coil combination so common in independent cord circuits. From a test which I recently made, the repeating coil is considerably less efficient as a transformer of speech than the condenser-retardation coil combination. Hence the insertion of the trunk repeater into the line will still leave the automatic with an excellent transmission circuit.

Where there are a number of groups of trunks from one office district to another, as from *E* to *A*, Fig. 21, it seems that there would be considerable advantage in making all the trunks more or less accessible to all the offices in that district. I ask Mr. Campbell if this can be done? If so, the number of trunks can be reduced and still have the same busy hour capacity as a whole.

For the benefit of many who may not now take kindly to the idea of an all automatic plant, I ask if the line switch or some other device can be used on manual boards to trunk small groups of subscribers to the office? My idea would be to place such a switch at the center of the subscriber group with as many trunks to central as necessary. When any subscriber in the group takes the receiver from the hook, he is automatically trunked to the manual board and answered by the operator just as if he were on an ordinary line. It would enable the giving of individual line service with as few wires as would be required for party lines. Has this been suggested or worked out, and is it considered practical?

John Wicks: This paper offers encouragement to those connected with the development of automatic telephone service. Few engineers have yet given the matter sufficient thought or study to enable them to see its possibilities. The fact that telephonic connections are made automatically has been viewed as a curiosity. That the public in large communities has made use of it for years, even in preference to the best manual service offered by competing companies, is still looked upon as incredulous. Many have wondered at its rapid general adoption, but few have stopped to investigate the reason of its growth. It is therefore interesting and gratifying to learn that it has developed along a line which makes it possible to decrease the great economic waste, which in the form of idle lines is to be found in the old style telephone systems.

Automatic telephone service has been tried sufficiently to prove itself practical. We know that the telephone-using public likes it. We know also that there are no mechanical or electrical difficulties in the art which cannot be overcome. To compete with manually operated telephone systems, therefore, it has only to prove itself economically more efficient than its rival.

In manually operated exchanges, party lines were long ago resorted to as a part solution of the problem involving the reduction of the percentage of idle lines. So important has this branch of the service been considered, that a prominent telephone engineer stated only a few years ago that a grave objection to the automatic equipment was that it had no party lines. The manufacturers of automatic switchboards have since then successfully solved the party-line problem, but it is hoped that the introduction of multioffice automatic switchboards will eventually do away with a large part of party-line service without putting the rental above the reach of present party-line subscribers.

The principal reason for the moderate price of party-line service is the saving effected in line construction by using one line for several telephones. A similar reduction in line investment is obtained by the use of a large number of small offices interconnected by trunk lines. It has the advantage of offering individual lines to patrons who can now afford only party lines.

A plan has been proposed and is now about to be tested in an eastern city which, if successful, will enable a telephone company to offer a still cheaper direct line service. This new service might be termed "limited trunk" service, because the scheme is to limit the number of trunks to the main office from the district station to which the limited trunk subscribers are connected. For example, if 100 telephones instead of being connected to the main central office by 30 or 40 party lines should be connected individually to a 100-line switch unit in a district station, this district station may then be connected to the main central office by a number of trunks less than that necessary for furnishing each telephone a trunk line whenever demanded. For instance, the number of incoming and the number of outgoing trunks connected to the line switch unit might each be limited to five, thus making a total of 10 trunks instead of 30 or 40 party lines. It can readily be arranged so that any party attempting to call when all of the trunks outgoing from the district station are busy, will receive either the ordinary busy signal, or preferably a peculiar signal which will inform him that all trunks are occupied for the moment and that he should call again in a few minutes. It often happens that one subscriber keeps a party line busy for an unnecessarily long period to the inconvenience of others on the line, but it would be impossible for any one or two inconsiderate subscribers to occupy all of the trunks from a district station. Another marked virtue of this limited trunk service is that communication would be absolutely private, thus eliminating one of the most objectionable features of party-line service.

There may be questions raised as to the advisability of having a small sub-station with its apparently complex line switches and connectors without an attendant, but experience has proved that even in the operation of large switchboards contained in one room it is done to a large extent through supervising signals. If a line becomes grounded or open, or if something goes wrong with the switching mechanism, attention is called to the matter by means of a signal, which may as readily be made to appear in another office miles away. Should the trouble be in the subscribers' line or instrument, no other part of the sub-station is affected, whereas a trouble in a party line will frequently throw all the instruments connected to that line out of service. Any part of the switching mechanism going wrong will affect only the trunk connected to that particular switch, and that can be made "busy" from the main exchange until it is convenient to repair it.

Apparently, rural or extremely isolated subscribers would still have to be furnished party-line service, but it would appear that multioffice and limited trunk multioffice service might be used both to the advantage of the telephone company and its patrons to dispense with the majority of the party lines.

The possibilities of limited trunk service will be still further enchanced, especially for residence districts, when the manufacturers of automatic equipment put apparatus upon the market that will make two-way trunks practical. It will then be unnecessary to have one group of trunks for handling outgoing calls and another group for incoming calls, but each trunk will be available for a call going in either direction. It is a well known fact that the maximum flow of traffic from the residence districts to the business district of a city does not occur at the same time as the maximum flow in the opposite direction. Consequently, if the trunks could be used in either direction a less number would be needed. Two-way trunk equipment is possible, in fact has been tried experimentally a number of times during recent years. It is my belief that it will eventually be made a commercial success.

E. A. Mellinger: Practically the only argument which can at the present day be consistently advanced against the automatic system is the first cost of the apparatus which, as indicated in Fig. 5, is considerably greater for a single automatic exchange than for a single manual exchange, except in cases of very large switchboards. In some instances this is a factor of more immediate importance in deciding what equipment shall be installed than is the comparative cost of operation and maintenance.

Mr. Campbell demonstrates the entire practicability of subdividing the automatic exchange to an extent not economically possible in manually operated switchboards. It is probable that, even with a comparatively limited subdivision, from 50% to 75% of the cable required for a single exchange can be eliminated. In comparison with the economy thus effected the additional first cost of the automatic switchboard is of small importance.

Since the cost of maintenance and operation of an automatic exchange is almost inappreciably increased by subdividing it into branches of 1000 lines or more, and since, obviously, the service is unaffected by such subdivision, the only items to be considered are the slightly increased cost of apparatus and buildings. With reference to the cost of apparatus, there can be no doubt but that there will be some increase with subdivision, owing principally to the present necessity for separate battery-supplying units; but in many instances there would be an actual saving in the cost of building on account of the comparatively low value of building locations required for the branch offices. The central exchange is usually located of necessity in the heart of the business district where land values are at the highest, and any reduction in space required would much more than compensate for a corresponding increase in branch office space. It is probable also that less expensive building construction could be employed in branch offices than in central exchanges.

For the small sub-station serving an outlying district it is customary to rent space in some office or store building or to erect a small building for housing the apparatus; but in an exclusive residence district it is sometimes difficult to obtain space in a suitable location. In at least one instance this difficulty has been successfully met by placing the sub-station under ground in a moisture-proof cement vault, similar to those used for housing batteries in railway signal work. The most logical location for a sub-station is usually at the manhole where the cable distribution for the district begins, and since no serious objection has been encountered in the installation and operation of the underground sub-station, there appears to be no reason why the manhole itself cannot be constructed to accommodate the switching apparatus, thus eliminating the necessity for building space.

The vault, or monolith as it is called, to which reference is made, was constructed complete in one piece before being lowered into place. It is elliptical, its dimensions being 4 ft. 10 in. by 7 ft. 8 in. by 6 ft. high, and accommodates a 100-line unit together with protector and distributing rack, batteries, etc. The average manhole is almost as large.

Carefully kept thermometer and barometer records indicate a practically constant temperature of 70 degrees fahr. and an almost complete absence of moisture, except as the presence of the troubleman or others in the vault for half an hour or more changes the normal atmospheric conditions. After such visits the vault is quickly dried by lighting an incandescent lamp for a short time. A small ventilating fan would doubtless prevent any moisture precipitation while the vault is open.

Every city has one or more telephone districts so far removed from the telephonic center that the installation of the sub-station is an economic necessity, particularly since the telephones in these districts usually yield smaller rentals than those centrally located. Such districts are being satisfactorily served by trunking stations of from one to five hundred lines in a number of automatic exchanges in various cities, but the limit of practical distribution appears by no means to have been reached. It is more than probable that in the no very distant future every large office or apartment building will have its sub-station trunking to the nearest branch exchange, even though the distance be only a few blocks, and that these trunking stations will in most cases be a part of the underground system.

From the underground sub-station to the underground branch exchange is not a long step, and although the branch office is usually of such size as to require the constant presence of one or more attendants, the necessity for artificial light and ventilation is hardly to be counted as a serious objection. The economy which could be effected in the business center of large cities by such an arrangement is apparent.

Morgan Brooks: Mr. Campbell's paper speaks of the economic waste represented by 90% of the wire plant being idle even in the busiest hours. Imagine, if you please, a much smaller waste, such as 50%, and it is evident that the busy signal would be received from half the calls. Good service demands a minimum of busy signals, and necessitates economic waste. The author has shown that the quickness of disconnection characteristic of the automatic system helps the service, especially with trunk lines, although it evidently increases the percentage of non-use. It is only in private branch exchanges that good service may be coupled with a reasonably large load-factor of subscribers' lines.

L. E. Hurtz: A word or two about these sub-stations. Mr. Campbell speaks from the manufacturer's point of view; I speak from the operator's point of view. A very large advantage, in the use of these sub-stations over the ordinary type of equipment is the fact that the exchange can be divided into units as small as one hundred lines. When considering the cable distribution of a telephone plant, the reasons that make it necessary to subdivide very large districts into several smaller ones are well understood. The question then arises as to the proper time to stop sub-dividing. In manual practice on account of the cost of buildings and equipment, and in order that satisfactory and economical service can be given, these branch exchanges vary in size from 1,000 to 10,000 lines, according to the density of the telephone development in that vicinity. With the use of low-priced buildings and low labor costs it is practical with these automatic switching units to reduce the size of these branch exchanges to one or several hundred lines, which increases the savings due to sub-division to a corresponding extent.

In our experience of a year and a half, during which time we have had two sub-stations in operation, we find we can give high grade service with but little additional labor. It is an easy matter to realize what vast savings can be made in the cable plant by use of this system. .The saving in investment and maintenance cost and interest cost must be equated against the additional labor; if the additional labor item is low enough there is a big saving. This system is being tried in several places. Our experience with it leads me to believe that it is thoroughly practical and will work out as well as indicated by Mr. Campbell.

I am convinced that one of the greatest developments made in telephony in recent years is the production of this switch unit. It is possible now to put in sub-stations as small as one hundred lines, locating them at isolated points, and at the same time not increase the operative and maintenance expenses to any considerable extent.

Samuel G. McMeen (by letter): The economic waste of which Mr. Campbell treats has been recognized for many years, and efforts have been made to reduce it in manually operated systems. In most of the cases the effort has been successful. The method of waste-reduction by automatic apparatus, as treated by Mr. Campbell, is the most important recent attack, and is one from which a very large amount of new knowledge may be expected to be drawn.

The broad idea of dividing a telephone exchange wire-plant into two general parts, and then using one part at a high efficiency and the other at a low, is not new. It has been proposed again and again, and has been developed for various forms of apparatus and various arrangements of wire-plant. The planetary system of operating manual equipment was such an effort, proposed eight or ten years ago by Mr. Angus S. Hibbard. In that system all calls needed to be trunked from a small local office, in which they were first received, to a central switching office, even though they might need to be trunked right back again to the small first office to find the sought lines.

The telephone requirements of the business area of every city is served very largely by private-branch exchanges, privately operated. About two-thirds of the traffic originating in them requires to be trunked to a main exchange operated by the telephone company. If these private exchanges were to trunk *all* their originated business, even at the cost of receiving again all local calls, such a plan would be a *manual* counterpart of the waste-saving system Mr. Campbell describes. As it is, the plan is a real counterpart so far as concerns the traffic for which, mainly, a private branch exchange exists, and the object is the same to save wire-plant at a cost for apparatus and attendance.

A proof of the widespread wish to make such a wire-plant saving is to be seen in the long effort to produce a selective and secret party-line equipment. It is possible to-day to have and use such a party-line system, but at best the privileges of the line are divided up among the subscribers upon it. None has the same good condition as the subscriber on a single pair of wires, all his own. In either manual or automatic practice, the amount of central office equipment is controlled by the traffic, which party-lines do not reduce, unless by discouragement caused by poorer service. All that a party-line can do, at best, is to save something of the annual cost of its line, and unless this line be longer than a certain minimum, nothing at all is gained, and always something in quality of service is lost.

A condition not brought out by Mr. Campbell may well be considered as next in importance to the savings. I refer to the saving possible in the *character* of lines, as distinguished from their *extent*. The subdivision of the plant, so as to have many and short subscribers' lines, connecting over long and few trunk lines, enables the kind of circuits of both sets of lines to be reviewed with great gain. What I mean is this: the facts which govern the choice of circuit elements for subscribers' lines are much dependent upon distance. The conductivity of the subscribers' loop governs the amount of current deliverable to his transmitter from a fixed-voltage central source. The capacity of the loop governs both transmitting and receiving. For a set standard of either, it is possible to distribute the lines of a subscribers' district, if that district be small, through cables of much smaller wires squeezed into a much smaller bundle and covered by a much smaller lead sheath, than if the district be a large one and the average lines be long. As the transmitter current problem is a direct-current distributing one, the analogy is that of large and small districts in direct-current power distribution, with the further advantages that the telephone problem involves great numbers of circuits, in each of which a small saving can be made.

For example, most subscribers' lines, in multioffice manual practice require cable circuits of No. 22 B. & S. gauge wires, having a mutual capacity of not over 0.06 mf. per mile and a resistance per mile of loop of about 190 ohms. Assume that a system satisfies working conditions with such cables when the longer lines of a district have a length of somewhat under two miles, and a loop resistance of, say, 350 ohms. If it were recast so as to be served by more centres, with maximum lines in each of a half-mile, a cable formed of No. 28 B. & S. gauge wires, pressed so tightly together as to have a mutual capacity of 0.22 m.f. per mile, should give similar results. Equally, wires of other metals than copper may be used, with a gain in certainty of jointing and terminating, and the reduced sheath diameter is accompanied by a reduction in its thickness.

The foregoing presumes that each small district contains its own source of current, so that the calling and the called subscriber each receives transmitter current over the minimum length of line. Experience with operating conditions shows this to be a preferred arrangement, for reasons other than transmitter supply; and the increased efficiency of transmission in private branch exchanges having localized current sources for trunked connections emphasizes the point.

Mr. Campbell's observation of the shorter holding of the line in an automatic system seems to be generally noted. It is a psychological matter more likely to be discovered than predicted. The same is true of quicker answering and less waiting for answer after actual ringing has been done. These differences in the actual performance of the two systems need to be considered in any study involving comparisons. The longer time of *initial* holding of inter-office trunks seems also to be overbalanced by the speed of disconnection in the automatic apparatus, and to this must be added a consideration of the slowing down of disconnecting efficiency on the part of the manual *B* operator during the rush period.

No casual study of large city work fails to show the beginner the influence of sub-division of districts on the amount of trunking. The percentage of calls trunked out of the New York

Cortlandt Street subscribers' board in 1896 was 75; in 1902 it was 90 or more, and to-day, under accepted manual practice for such surroundings, it is 100; that is, it is not worth while to complete any call directly in a manual multiple of lines when so few as a tenth of them can be so completed. Mr. Campbell's point of trunking all calls in an automatic system is of equal force in view of that tendency in manual practice, and of the present trend of thought in partly automatic manual systems.

A feature on which more might have been said is the possible danger of excessive changing of subscribers' numbers. It must be admitted that anything which endangers a subscriber's privilege to keep the same telephone number through a term of years is a bad thing. In a one-office exchange that danger is least, and under ideal conditions may be nothing, for the main distributing frame in that one office enables the central office equipment to follow up his line, into whatever quarter of town he may move. But in a multioffice system, it is a penalty upon the subscriber that he must change his number when he moves from district to district. The more districts there are, the worse it is for him. But it is further a hardship that in cases of relief of congested regions, as suggested toward the close of the paper, a subscriber may awake to find his number changed overnight, through no fault of his own. Certain care in districting regions, and certain stubbornness in following the resulting plan, will prevent a large part of the changes required by future splitting of original sub-office districts. It is strongly to be recommended that this forecasting be done, for the number-changing evil is one in which party-line and sub-office systems are alike responsible.

W. Lee Campbell (by letter): Professor Smith asks if it is possible to make all of the trunks from *E* office to *A* office in Fig. 21 accessible to all of the subscribers. It is possible, in fact equipment of the necessary type has already been installed for trial and is operating satisfactorily.

He also asks if line switch sub-stations could not be used with manual telephones in connection with a manually operated central office. I would reply that they could be, and probably will be.

Concerning the plan for relieving a congested district by converting the line cable into a trunk cable, I wish to say that this would often improve transmission from the original telephones, because it would bring the battery closer to the transmitters drawing current from it.

This feature might even permit the district to be enlarged; that is, new patrons farther away might be added and their transmission be equal to that afforded the original subscribers, before the new local office was installed.

I think that in economically designed plants the conductors of the trunk cables are not made heavier than the lines unless the distances are so great that heavier wire is necessary to keep the transmission up to standard. In other words, the subscribers in the district reached by such a cable would have to be served by heavier conductors if no branch office were installed in that district. I see no reason, therefore, why adding to the number of offices should increase the amount of large conductor cable used for trunks; it appears to me that it would tend to decrease the amount.

DISCUSSION ON "ENGINEERING FEATURES OF THE SOUTHERN POWER COMPANY'S SYSTEMS." ATLANTIC CITY, N. J., JUNE 30, 1908.

(*Subject to final revision for the Transactions.*)

J. H. Finney: I believe that many of us here fail to realize the actual value of the work that has been done by the Southern Power Company in the south. I think that there are not many electric plants in this county that I have not seen at one time or another, and I believe the work that has been done by developing the water power system of the Catawba river by the Southern Power Company is as creditable as any similar work in the United States. It is well worth a visit to go down and see that Great Falls plant, the Rocky Creek plant, and the others there.

W. S. Lee: Perhaps a good many engineers do not know the conditions that we have to meet on southern streams. There is an erratic flow, a flood discharge on several of these plants one hundred times the minimum discharge; this means quite a problem in designing the structure from the hydraulic end, as well as trying to apportion the station equipment so as to use the secondary power to the best advantage. We have studied this condition carefully, and while we have adopted the plan of putting in station equipment about one and one-half times the minimum low-water requirements, naturally there is a possibility of even changing that, due to the fact that a great many southern cotton mills have efficient, large steam plants. We are now offering power for sale on a six month's basis, which we call six months' secondary power, at a much lower price. This six months' power is an inducement to the large plants, which can run six months on steam and six months on water power. In some years the water flow is a little greater, and the mills can then be operated by water power eight months, or even ten months, and on rare occasions, twelve months in the year.

We first had a great many 550-volt motors on the cotton mill work, and were endeavoring to make the voltages multiples. We saw at once that in cotton-mill work it was not advisable to install a 44,000-volt sub-station for each mill, consequently almost all installations are now using 2200-volt motors. We have towns in which we operate seven or eight mills from 200 to 500 h.p. each, where it is possible to locate one sub-station. All of our transformers are wound for 550 and 2200 volts on the low-tension side, and 11,000, 22,000, and 44,000 volts on high-tension side.

Reference to the map will show the location of the Great Falls station, Rocky Creek station, and Fishing Creek station. Great Falls station being between the other two, it is our intention to feed Rocky Creek and Fishing Creek stations into a common switch house or bus-bars, which will be located at the Great Falls station. This will enable the attendants at Great

Falls station to control all lines or feeder circuits. We are also designing an 88,000-volt transmission line from Great Falls to Spartanburg, S. C. The transformers and control of lines for this voltage will also be handled by attendants at Great Falls station.

D. B. Rushmore: The plant of the Southern Power Company is one of considerable interest. The voltage of the plant, 44,000, was the maximum conservative voltage at the time of installation. At present one would use a higher potential for such conditions. Efforts should be made to standardize transmission voltages. Below 44,000, the figures are fairly well fixed; above, there exists a wide variety of voltages. We must either decide on delta-star combinations or else choose some arbitrary figure. For high voltage transmission work one does not change the system of connections from delta to star after the first decision has been made, therefore an arbitrary decision on multiples of eleven seems the most logical basis. The following voltages are recommended for transmission work: 6600, 11,000, 22,000, 33,000, 44,000, 66,000, 88,000, 110,000, and 165,000; 66,000 is already in operation in so many places that it already has an existence; 88,000 is taken as the double of 44,000. On transmission lines it is often desirable to double the voltage and to wind transformers for the higher voltage, using them for parallel connection on the lower voltage. A large number of plants are now being installed at or about 100,000 volts. It seems desirable to fix this figure at 110,000, these voltages being the voltages at the generating station. 165,000 is proposed for the next step.

One of the factors which has entered into the successful operation of this plant has been the use of 60,000-volt insulators on the 44,000-volt line. The greater margin of safety is one of the results of experience in this line of work.

It is to be noted that this system employs a delta connection on the transformers on the high-voltage side; also that a compromise is effected concerning the use of transformer compartments, and that the high tension wiring is entirely open.

A feature of especial interest is the use of expulsion fuses instead of automatic switches for protecting the sub-station apparatus. It is understood that this feature has been very satisfactory.

P. M. Lincoln: I agree with Mr. Rushmore that it is desirable, if possible, to fix high-tension voltages in advance of their use but I am not sure that it is best to eliminate the 88,000 volts. There are a number of plants in which this voltage is proposed; the reason for it is that the plants are to go in at first at half that voltage, 44,000 volts, while the amount of power called for is small, but they are being installed with the intention of eventually doubling this voltage. The fact that there are two different but obvious methods by which transmission voltages may be increased is responsible for the existence of the odd voltages.

Voltages may be increased either by doubling the previous voltage or by throwing delta-connected transformers into a star connection. In the former case the factor of increase is two and in the latter $\sqrt{3}$. With this constant tendency toward odd transmission voltages the adoption of standards becomes all the more important.

In regard to the question of delta- versus star-connected transformers, I think that the selection of delta or star connection depends largely upon whether the neutral of the high potential system is to be grounded or not. If the grounded neutral is to be used, the star connection of the high-tension side is essential to obtain a neutral point. If the grounded system is not to be used, there is not much choice between the delta and the star. It is true that the star-connected transformers are somewhat less in cost than a similar set of delta-connected transformers, but this is not a controlling advantage. The whole thing hinges upon the larger question of whether high-tension transmission system is to have a grounded neutral or not.

Chas. P. Steinmetz: I desire to commend the engineers who have designed this plant, on their conservative way of choosing transmission voltages and transmission lines, which ought to go a long way to maintain the record of reliability of operation acquired by the smaller station, of which this big system is the successor. Many of us do not realize the enormous work which is being carried on in the electrical development of the South. We read, and have heard, for many years of the long-distance transmissions in the West and Central states. Great results have indeed been accomplished there, where coal is almost out of the question by reason of its price, and where the distances are long and the voltages high, but not all of us realize that similar development is going on in the South. The development may not be of greater magnitude, but it is under different conditions, in competition with steam. The southern plants do not supply mines and towns which do not mind an interruption once in a while; they supply consumers like city lighting plants or cotton mills, where it is a serious matter to shut down and throw hundreds, if not thousands of hands out of work. There more conservative voltages must be used, and while 100,000 volts may be all right in the West, they are a little high for the South.

It is very encouraging to see how a system of enormous magnitude, fully as large in kilowatt capacity and in extension over distances as any western system, has chosen 44,000 volts as the trunk line voltage for transmission, using half or quarter thereof for the high voltage distribution system, and leaving it for the future, when necessary, to use a line of double that voltage, 88,000 volts.

Fourteen years ago the first cotton mill was installed in the South with electric drive. It is hard to realize how the whole South has rapidly developed commercially, and how electric power is coming to the front. Water power systems are also being developed. It is encouraging to see that this great development has been on conservative lines, and it is to be hoped, that as a result of the development of these systems, we will be able to say that long-distance transmission distribution is reliable, as reliable as local distribution, and that it will not be necessary to say, among ourselves not to the public—that long-distance transmission is ideal where you get the power, but after all you never know whether you will get the power or not.

DISCUSSION ON "FUNDAMENTAL CONSIDERATIONS GOVERNING THE DESIGN OF TRANSMISSION LINE STRUCTURES."

ATLANTIC CITY, N. J., JUNE 30, 1908

(Subject to final revision for the Transactions.)

N. J. Neall (by letter): It may properly be said of a transmission line structure that factors of safety are both necessary and expensive. It is naturally desirable, therefore, so to shape the design and so to adjust it to its operating requirements as to secure a maximum of service with a minimum of outlay.

There are two factors of safety that must be considered: 1. That relating to the transmission line conductors directly. 2. That of the tower itself as an independent structure. These will be discussed as follows:

1. Factors of safety relating to transmission line conductors. Once the amount of power to be delivered has been determined, together with the location of definite geographical points of distribution, a fundamental size of transmission wire can be deduced to carry the load economically. This should then enable a decision as to the permissible length of maximum span and an adjustment between conductor size, span, and cost of support (substituting other sizes of conductor if necessary) until the best proportions of cost have been obtained.

The next step is to decide whether the tower is merely to act as a support for the wires without further responsibility, or to hold them up against any ordinary accident; in other words, whether it is to be what is commonly known as a "dead end" structure. If the latter, a much stronger pin support is required and may, because of the generally low natural limit of strength of such a feature, require several or more such supports in tandem and special arrangements for holding the wires to the supports.

2. Inherent structural characteristics effecting factors of safety. Theoretically it is desirable to have a tower or transmission line structure flexible in the direction of the line, and inflexible perpendicularly thereto. It is assumed that any wind blowing parallel to the line does it no harm, while a high wind perpendicular to the line is a serious feature; in other words, the tower must be able to resist being blown over. This consideration immediately affects the shape and size of the tower, to which, in turn, such items as wind pressure per square foot, form of anchorage, nature of soil, etc., add their quota of requirements.

For such a structure pure and simple, the requirements of endurance are obvious and of little concern to the electrical engineer, save that the character of the design will permit of the special loads being applied without any impairment of the structure as such.

It is but a step, then, to combine these two elements; in the usual specification the loads brought on the tower by the transmission wires are the only ones specified. It is here that I think there is much room for improvement over present practice.

When it is borne in mind that both the tower itself and all conductors are simultaneously affected by any of the usual elemental conditions considered in this connection, such as heat, cold, wind, dead weight, ice or sleet, etc., and since moreover it is found in usual requirements that a safe length of span to stand minimum temperature with ice or sleet and wind blowing simultaneously at a maximum velocity determined by local observation to be applicable to this case is taken at the condition of maximum strain on the conductor, it becomes clear that the only true criterion of suitability of a structure is to test it preliminarily for design in such a way as to imitate as closely as possible just those strains that come upon a tower in service. The two extremes usually taken are the one for minimum temperature, sleet, and relatively low velocity of wind; and the other, maximum temperature and highest wind velocity. With reference to the tower, the former may be considered for the present as less serious than the latter, principally since dead weight is such a large factor in the cold, and sleet condition and structures for transmission lines are thought to carry this more easily than the maximum wind condition.

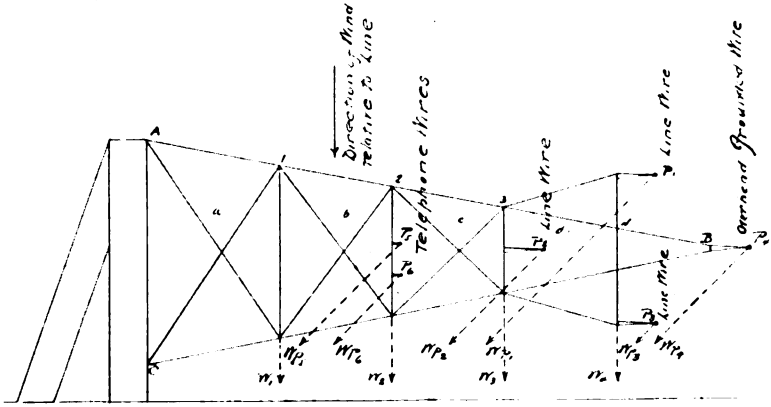


FIG. 1.—Loads on tower for maximum temperature and minimum wind velocity.

In order to test the tower, once the line details have been preliminarily worked out, two methods are possible.

First, the tower is mounted on a concrete or other firm foundation and loads applied at various points by means of cables suitably equipped with a dynamometer, or, more conveniently, as follows.

Secondly, the tower fastened horizontally. Let *A B C* represent the structure fastened rigidly to a strong support. Then by calculation the resultant direction and amount of dead weight of wire and wind for the wire when two adjacent spans are in equilibrium can be determined, and the load corresponding thereto can be suitably applied to the tower, as shown by Wp 1, Wp 2, Wp 3, etc. This is the only load brought on the tower by the conductors for this condition of the weather, viz., maximum wind and maximum temperature.

By a proper calculation the total stress on the tower can be determined. For the purposes of this test, these loads are best applied at the girts 1, 2, 3, etc., as shown on diagram, and are indicated by W_1, W_2, etc. For the horizontal position the dead weight of the tower must be taken into account, and W_1, W_2, etc., represent the additional amount to equal the calculated values.

From this it is obvious that any of the conditions applying to tower operation can be properly investigated. For example, one test can be made of "dead end" structures, where the strain in the wire (much in excess of that used as its dead weight and wind exposure pressure per support for towers under the usual service requirements) is appropriately applied at the insulator pins.

Horizontal strength or resistance to twisting from one or more broken wires (known commonly as torsional strength) under any given condition can be easily worked out.

The maximum amount of load which should be applied under these circumstances should depend on the given conditions of the test. I think that an all-round factor of safety of 2 will well meet most commercial requirements, particularly if the test is made for a condition of maximum weather effect.

It is easy to argue that if minimum temperature, sleet, and wind are the worst for the wire and that as a matter of design this strain is made equal to the elastic limit of the conductor, we have roughly a factor of safety of 2 against breakage, coupled with a relatively remote possibility of occurrence. The same basis of selection might apply to the structure as well. The usual specification for a given pull at the insulator pins is only a quasi-wire strain; it is practically a test of the strength of the tower built up to the pin strength as a basis.

Structurally, the insulator pin strength is the weak point of the ensemble, an average pin strength of approximately 1500 lbs. to 2000 lb. does not give much leeway in the use of a single pin for dead end work, nor for a large factor of safety. It is surprising, however, how much can be obtained from a given weight of material if properly disposed.

Some time ago I tested two towers in the manner described, the only difference of importance being the method of holding the diagonal rods *a*, *b*, *c*, and so forth. The builder of the tower employed what I have termed a button and buttonhole method of attachment for the diagonals to the girt. The rod being provided with a button-like end, the girt being cut button-hole-wise to receive this. In the second tower the diagonals ended in loops and were held by bolts, washers, and nuts to the girts or corner parts respectively, as happened to be. The total weights were not sensibly changed, and yet the latter arrangement showed itself much the stronger.

Strangely enough, the first tower had been successfully tested according to specifications by heavy loads applied to the pins when in an upright position. The second method showed easily how unsatisfactory the other might be as an indication of all-round strength.

The result of all this is a better appreciation of the behavior of the tower under service conditions, and leads directly to the conclusion that in this wise purchasers of towers can obtain a high degree of economy of tower material for a given amount of money.

In these discussions before the Institute cost is more than likely to be treated academically. In no place is it more critical, however, than in the problem of selection of a transmission line support; in fact, despite the many advantages of tower construction over its predecessor—the wood-pole line—the first cost of a metal tower line constantly tends above the wood pole, and of this the tower alone plays a large part, and increasingly so as the factor of safety increases.

With careful selection of design, such a line construction can be kept within reasonable limits; but to this end it is necessary to emphasize the point that not all towers should be dead-end towers; in fact, comparatively few may be so, and the remainder must be something less than this.

Since continuity of service is the final measure of success, in such a case it seems to me that any detail of construction used in this connection should be tested *destructively* for type before acceptance. In my judgment the test herein described is no more burdensome on the tower than standard arcing-over tests, etc., now employed for insulators. Each seeks to determine the ultimate strength of the respective detail under its known possibilities of service.

Ralph Bennett (by letter): The available data on existing transmission lines must necessarily be of a negative character, for a line is built to stand. It does so; therefore it is satisfactory. The margin of security in such a case is difficult if not impossible of determination.

A factor of safety of 2 against the greatest combination of known and assumed strains seems inadequate unless the strains themselves contain a large excess allowance. The following uncalculated strains occur to a greater or less extent in every tower: 1. Irregular loading due to settlement of footings and to uneven cable tension. 2. Load due to vertical and horizontal angles too slight to warrant special towers. 3. The results of line and side guying. 4. The racking effect of unequal adjacent spans under temperature changes.

A factor of safety of 2.5 against the extreme load would give a margin between the total calculated loading and the elastic limit of 25% of the load. This should be sufficient to produce a line which would stand in any weather. It is not sufficient to build a line which would just fail under the extreme weather condition which can be expected. A line important enough to warrant steel or concrete towers will warrant sufficient expense to make it secure.

The Kern River Transmission of the Edison Electric Company was designed in 1905 and erected in 1906-7. It has now been in active service slightly over 12 months. Part of the towers have had wire on them for two winters.

The essential features are as follows:

Standard span	700 ft.
Size of cable	4-0 copper, 7 strand
No. of cables	9
Average height above earth	57 ft.
Base at earth	12 by 12
Depth of footing	6 ft. 6 in. extreme.
Diameter of footing plate	24 in.
Type of tower	4 post
Tower bracing	tension rods
Total wind load on wire (22.5 lb.)	6300 lb.
Dead load due to wire	4050 lb.
Extreme longitudinal load (due to to failure of one wire)	3000 lb.

No sleet or snow; no temperature below 20° fahr.; maximum temperature 130° fahr.

At this writing the only difficulty experienced with the line has been due to eagles which roost on the lower cross-arm between the insulator and the upright. In flapping their wings preparatory to flight they cause a short-circuit from the wire to the structure. In a few cases this has burned the cable off. No tower failures have resulted from this or any other cause. Most of the line has as yet but six cables, and as a consequence there are as yet no data on the effect of side winds. But the absence of three cables renders the effect of cable failures and guying much more serious than it will be in the completed line.

Before issuing the tower and wire specifications an experimental span of 1000 ft. of a single 19 strand 00 copper cable was observed at intervals during about a year. Its performance in respect to temperature change was very closely in accordance with calculated values. The methods of measuring wind proved to be so crude that the results were indeterminate. Other observations were made with rods of various shapes projected from the side of interurban cars. These results were also only approximate. The average of a large number of observations indicated that the pressure on round rods was less than six-tenths of that on thin flat rods of the same projected area for any velocity up to 30 miles per hr.

The method of figuring footings given by Mr. Scholes is based on the angle of repose of loose sand. This can scarcely apply in firm or sticky or flowing soils. Most tower footings are in soils which are at least self-supporting. Such materials as gravel and stiff dry clay are very slow in recovering their original firmness, even if tamped thoroughly. Meanwhile a footing placed in a straight sided hole is liable to lift the loose dirt out along the line of disturbance with a much less load than that calculated by any formula based on an assumed cleavage line. If, however, the earth is firm enough to permit of enlarging the hole at the bottom so that the sides overhang the footing plate, the completed footing may hold more than the calculated amount, for the angle of repose of such a soil in a massive body such as that surrounding the foundation may be much greater than that of sand.

In setting guy-plates no lineman would think of so placing them as to bring the strain against the disturbed earth. In ordinary pole-line construction the disturbed earth is subjected to direct compression only, yet the only valid reason for the deep holes commonly used is to bring the point of maximum loading on this earth, so low that it will be held from flowing under the pressure by the firm earth surrounding it.

Where economy would demand the minimum cost to such an extreme as to render the skimping of footings necessary, would not the use of guyed towers instead of the self-supporting types result in a more reliable construction? Such towers would be much lighter; they would occupy less room at the base; they could be so constructed that the longitudinal guys would also take the side strains; and all earth plates would be against firm undisturbed earth. Since the variation in load with length of span affects the wind load as much as the dead load, and as any tower which will stand the stress of erection will stand the dead load, the towers could be adjusted to their loads by changing the number or size of the guy wires. The total weight would be low, as would the erection cost. The parts would be stiff enough to stand erection strains without the elaborate precautions taken on one or more of the lines recently noted in the technical press. It seems almost a truism to say that in construction of this character the parts should be few and rugged so that the money saved on shop cost need not be lost in the field in the handling of fragile members or the locating of a large number of small pieces.

Discussion on "Double-Deck Steam Turbine Power Plants." Atlantic City, N. J., July 1, 1908

(Subject to final revision for the Transactions.)

C. W. Ricker: The additional data which I have to present should properly have been included in Mr. Bibbins' paper, but as an analysis of all the vouchers had to be made to determine these data, which could not be done in time, they will be offered as discussion as briefly as possible. The data are as follows:

YOUNGSTOWN & OHIO R. R.—WEST POINT POWER STATION
Analysis of Cost of Completed Plant, 3000 kw.

Building and fixtures,	*Cost*	*Per kw.*
Foundation, general excavation, and concrete work including condenser wells and overflows and ash tunnel; steel frame and building superstructure, ash-handling apparatus, coal trestle, chimney, smoke flue, and crane	$64,204	$21.40
Boiler plant,		
Six 400 h.p., No. 200 water-tube boilers, settings, furnaces, pumps, heater, piping and covering	42,726	14.24
Condenser plant,		
Three barometric ejector type condensers with separate centrifugal pumps, water intake and dam including deepening channels	19,224	6.41
Generating plant,		
Three 1000-kw., three-phase, 25-cycle, 400-volt turbo-generators. Six 375-kw., 22,000-volt step-up transformers, duplicate exciters, switching, and protective apparatus	112,764	37.59
General expense,		
This includes items not susceptible of distribution and part of the expense of supervision	7,252	2.42
Complete	$246,170	$82.06
Sub-Station equipment in power station.		
Two 300-kw. synchronous converters with five-panel switchboard	12,600	4.20
Total	$258,770	$86.26

This, of course, is a comparatively small station and the items of general character, mainly in the building and fixtures, are necessarily larger in proportion than they would be in a station of greater capacity. These costs were also increased materially by the position of the station, which is some seven miles from the nearest steam railroad station at which freight could be received. The entire building frame and steel work, and all of the cement and sand used in the foundation and water and ash tunnels, and the machinery and tools used in preparing and erecting these items, had to be hauled over seven miles of bad country roads with steep grades at an expense of from $2 to $4 per ton, which amounts to a considerable item.

The station building has a complete steel frame, which was erected on the foundations, before the brick work was begun. The accompanying photograph shows the completed frame.

To show the steadiness of the station, a photograph was taken by the Cooper-Hewitt lamps used for general lighting.

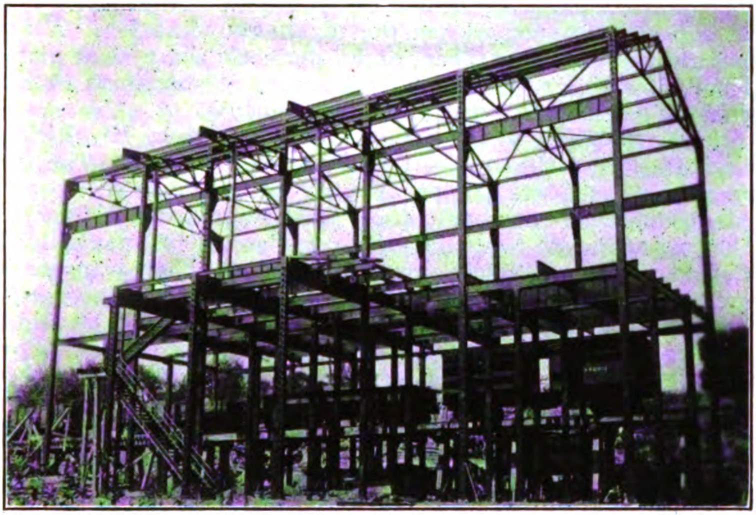


FIG. 1—West Point power station steel frame.

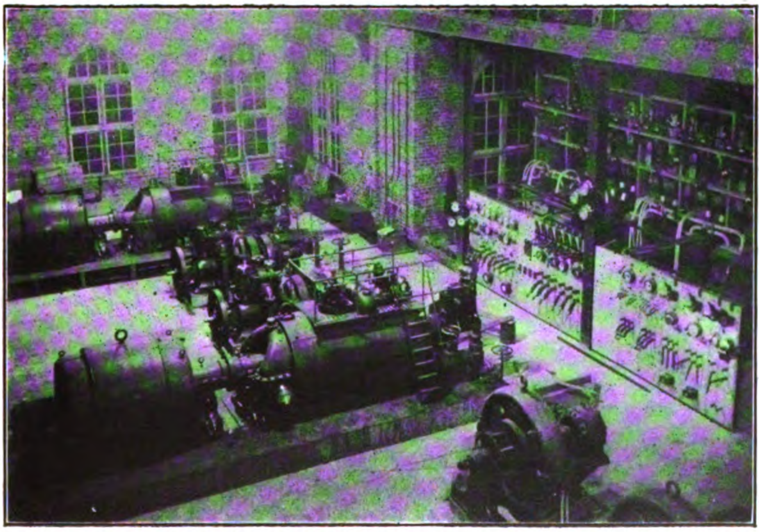


FIG. 2—West Point power station from top of crane.

A portable box camera mounted on a light tripod was set up on top of the crane which is about 33 ft. above the station floor, in a position to experience the maximum vibration. A two-minute exposure was taken, and a perfectly sharp clear picture resulted, which seems to show a degree of steadiness at least entirely sufficient for operating requirements.

J. R. Bibbins: I am exceedingly gratified in Mr. Ricker's presentation of the cost of the West Point station. The total figure he has quoted, approximately $82 per kilowatt for the plant complete, corroborates the figures noted in the paper for the cost of the Ft. Wayne station complete, $66.25 per kilowatt. Considering the largely increased expense in transporting erecting and building materials to a comparatively inaccessible location, it is safe to say that a station of this kind could be duplicated in a city like Ft. Wayne for even lower cost. For a complete power station of high-grade construction throughout and only 3000 kw. capacity to total as low as $82 per kw., emphasizes the principal theme in this study of power station construction. With these two excellent examples before us, the double-decked type station should, in future station work, evidently receive the thoughtful consideration of every power plant designer.

This type is applicable not only to the turbine, but also to producer gas plants of considerable capacity where the relative location of power machinery may be reversed to good advantage —the engines upon the ground floor and producers, scrubbers, and all auxiliaries on the second floor. Recently a 16,000-kw. plant was designed for a large city railway system, in which the ground floor area was only 2.25 sq. ft. per kilowatt, accommodating eight 2000 kw., tandem, horizontal gas-engine units and 24,000 h.p. in producers, all in a building 336 ft. long, 107 ft. wide and 82 ft. high, to the lower chords of the roof trusses. In this type of plant the building structure is comparatively light by reason of exclusively static loading and the absence of extremely heavy parts in producer-gas apparatus.

DISCUSSION ON "INDUCTION MOTORS FOR MULTISPEED SERVICE WITH PARTICULAR REFERENCE TO CASCADE OPERATION."

ATLANTIC CITY, N. J., JULY 1, 1908

(Subject to final revision for the Transactions.)

W. I. Slichter: There is a point in the subject of cascade connection of induction motors which the speaker would like to hear discussed, as it is particularly important in connection with railway engineering. The usual and first idea of the result of the cascade connection of induction motors is that it will make it possible to obtain from a given pair of motors a greater torque at a low speed than is obtained in normal operation. But a closer study of this subject shows that the maximum torque of two motors connected in cascade is always less than that of either one of the individual motors. This is a proved fact with regard to the operation of motors with like number of poles, but it would be interesting to know what the relation is with motors having different numbers of poles.

A. E. Averrett: I have found that in general concatenated coupling, when used for a very small range of speed, will work out quite nicely, as it is comparable to a relatively small change of voltage, with a compensator or autotransformer, but as the range of speed increases, the effectiveness of the concatenated set decreases. The second motor has all its power carried through the first motor, and the first motor will have a great impedance drop, so that the effective voltage of the second motor, after the current has passed through the impedance of the first motor, is low. Furthermore, the concatenated motor acts similarly to a single two-speed motor. The lower the speed of any induction motor, the lower the power-factor; that is, in case the speed reduction is by a change of poles. A constant-speed, collector-ring, induction motor will maintain approximately constant torque with an efficiency in proportion to the speed; a concatenated or multispeed motor, where the change of speed is made by shortening the pole pitch, will maintain fairly constant efficiency, but the power factor goes down with the speed reduction. In concatenated motors the problem is nearly as much of a mechanical as an electrical problem; the diameters become small, distances between bearings centers increase, and with the slow speed which we are really trying to maintain the question of ventilation becomes important. There was recently built a concatenated set for a very peculiar service, rolling mill work, where the concatenated motors were 20 and 16 poles, and the combination 36 poles. It happened that the power required for the actual concatenation work, at 36 poles, was very slight, the main power being at the 20- and 16-pole speeds.

Most motor work will require constant torque or perhaps torque increasing as the speed drops (constant power). In these cases, the low power-factor of the concatenated motor renders it extremely difficult to make a good combination at the low speed; but for a close range to the normal speed, as before stated, the concatenated motor works very well.

Elmer A. Sperry: Can anybody here throw light on the subject of returning power to the line when this class of motors is employed in traction service, coupled as described?

H. C. Specht: It has been asked if two motors connected in cascade would give any more torque than one of the motors. This certainly is not possible unless auxiliary devices are used. The motors connected in cascade will have somewhat less or not more torque than the average of the two motors, and the reason is simply that the current has to pass through both motors, which increases the leakage. As was mentioned at the end of my paper, it is a problem of finding a good phase compensator, to eliminate the most objectionable features of cascade connections.

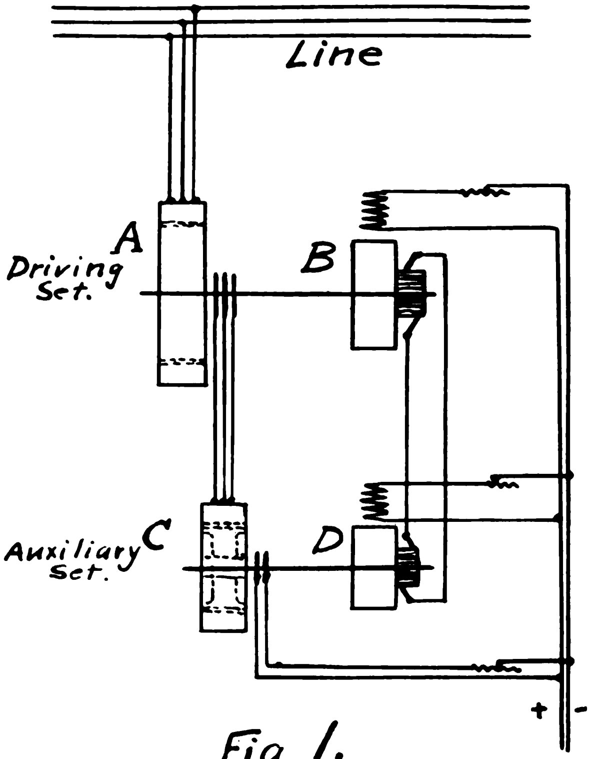


Fig. 1.

In regard to compensated cascade sets, I would like to mention that several schemes have been suggested in the last few years. Whether or not any of these schemes will be adopted for general use and give satisfactory results, is yet an open question.

The method generally used for compensation is that of connecting a synchronous motor or a compensator induction motor in the secondary circuit. The motors are then regulated so as to produce a leading current. Since this current, with the primary current and the magnetizing current of the main motor, form a triangle, it is possible to raise the power-factor not only to *one* but to obtain an over compensation or leading current.

The following will serve as examples of the methods referred to and as described recently by Heyland, Willner, and Kubler in German technical periodicals.

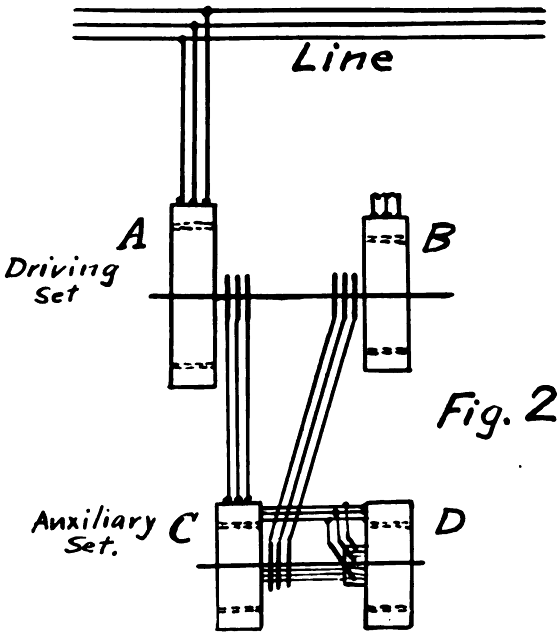


Fig. 2.

Fig. 1 shows an arrangement with a synchronous motor (*C*) in the secondary circuit. On the same shaft with the latter motor is a direct-current generator which supplies current to the second driving motor (*B*) which is, in this case, a direct-current motor. The direct-current machines and the synchronous motor are excited from a separate direct-current circuit.

In Fig. 2, compensation is accomplished by means of a compensated induction motor (*D*) connected to the secondary circuit of the main driving motor and to the other induction motor (*C*), which latter is mounted on the same shaft as the compensated motor, and serves as a frequency changer.

The second driving motor (*B*) is also an induction motor and is connected to the secondary circuit of motor (*C*).

In Fig. 3 is shown a method similar to that in Fig. 1, with the exception that the synchronous motor (*C*) is replaced by an induction motor, the secondary of which is connected through the collector rings to the armature winding of the driving motor (*B*).

The foregoing methods serve not only to compensate the power-factor, but also allow of starting up the tandem set with a great deal less kilowatt input than would be required in the case of ordinary induction motors, on which a great deal of power is wasted on the secondary resistance. It likewise increases the maximum running torque over that of an ordinary cascade set.

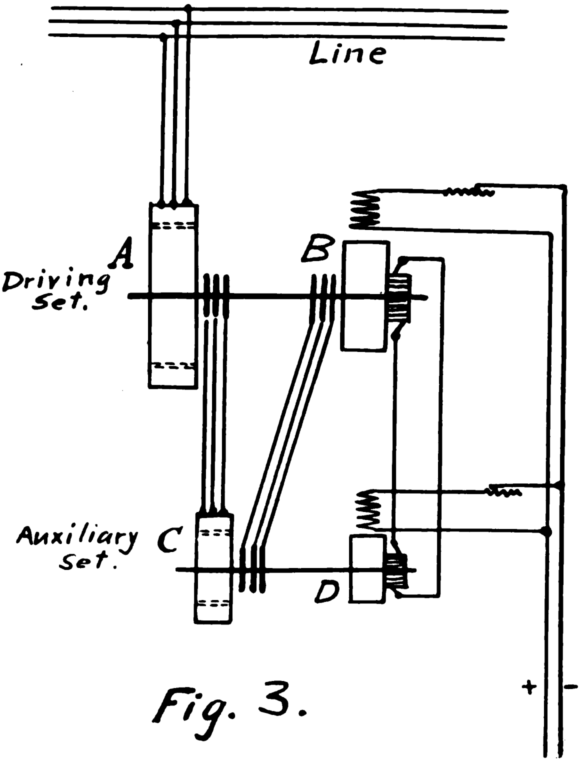
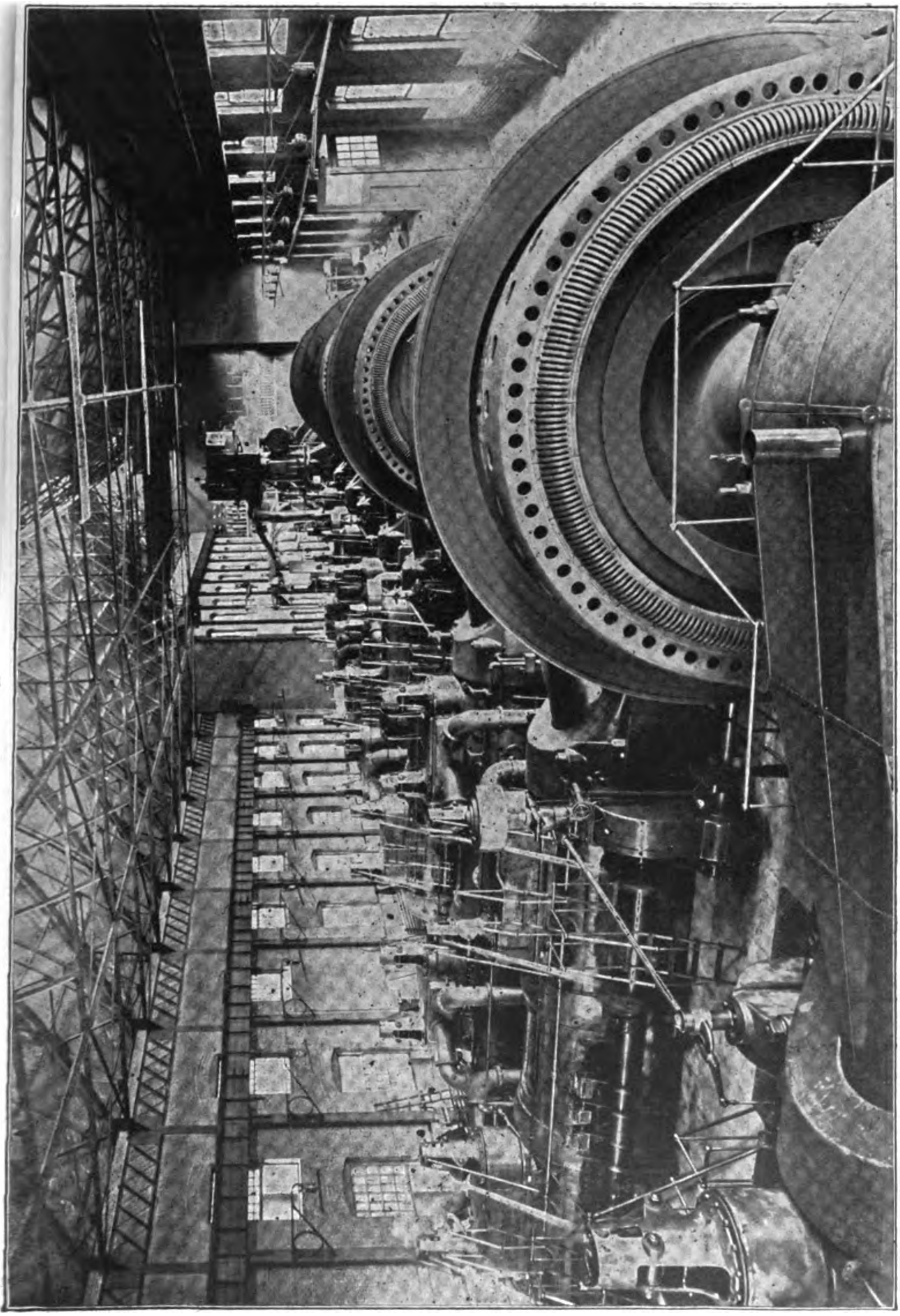


Fig. 3.

In addition, the schemes as shown in Figs. 2 and 3, permit of reversing the set in a comparatively short time and with no sudden rush of current, as the inertia in the two driving motors is kept small. The flywheel on the auxiliary motors serves as a storage for kinetic energy. For obvious reasons these latter should be designed for high speed.

Further, we see that the methods above described allow of running tandem sets at variable speeds with the minimum waste of energy. In some respects they are similar to the Ilgner & Leonard reversing systems.

The method as shown in Fig. 3 would seem to contain possibilities in connection with hoisting, rolling mill, and traction service.



Allis-Chalmers Gas Engines driving Allis-Chalmers Generators in the new power plant of the Illinois Steel Co., South Chicago.
Aggregate capacity 10,000 kw.

DO THEY?

Do the consulting and contracting engineers, the chief engineers, superintendents, and other officers of lighting, railway, power, telephone and manufacturing companies know your products as well as you want them to? If not, do you know a better advertising medium for reaching these men than the PROCEEDINGS?

ALPHABETICAL LIST OF ADVERTISERS.

	PAGE.
Allis-Chalmers Co	i
American Bell Telephone Co	xviii
Arnold Co., The	iv
Arnold, Bion J	iv
Baker & Co., W. E.	iv
Baldwin Locomotive Works	xxiv
Barstow, W. S	iv
Bates, Putnam A	iv
Baum, F. G. & Co	iv
Bement, A	iv
Bissell Co., F	xii
Byllesby & Co., H. M.	iv
Clement, Edw. E	iv
Crocker-Wheeler Co	xxi
Cutler-Hammer Mfg. Co.	xvi
Cutter Co., The	xvii
Duncan Electric Mfg. Co	xvii
Electric Controller & Supply Co	viii
Electric Storage Battery Co	iii
Electrical Testing Laboratories	viii
Fibre Conduit Co	xx
Foote, Pierson & Co.	xviii
Fort Wayne Electric Works	xxi
General Electric Co.	Inside back cover
General Engineering & Contracting Co	v
Henshaw, F. V	v
Hill, Nicholas S., Jr	v
Hemingray Glass Co	xii
Howson & Howson	v
Jackson, D. C. & Wm. B.	v
Jones Co, Fred A.	v
Kellogg Switchboard & Supply Co	xix
Krantz Mfg. Co., H	ix
Moloney Electric Co	xiv
National Brake and Elec. Co	xxiii
Pierce, Richardson & Neiler	v
Roebling's Sons Co., Jno. A.	Back cover
Rosenbaum & Stockbridge	v
Sanderson & Porter	v
Sargent & Lundy	vi
Smith, Jesse M	v
Smythe, Edwin H	vi
Sprague, Frank J	vi
Stanton, LeRoy W	vi
Stitt, Frederick S	vi
Storer, Simon B	vi
Syracuse University	vii
Thomas & Neall	vi
Thompson, Edw. P	vi
Townsend & Decker	vi
VanNostrand Co., D.	Inside front cover
Vansize, W. B	vii
Wagner Electric Mfg Co	xiv
Ward Leonard Electric Co	xi
Western Electric Co	xx
Westinghouse Electric & Mfg. Co	xxiv
Westinghouse Machine Co.	
Westinghouse Traction Brake Co.	xxiv
Weston Electrical Instrument Co.	x
White & Co., J. G	vii
Wightman, Merle J	vii
Zabel, Max W	vii

(For Classified List of Advertisers see page IX.)

A paper presented at a meeting of the Toronto Section of the American Institute of Electrical Engineers, Toronto Ont., February 20, 1908.

Copyright 1908. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

ALTERNATING-CURRENT FEEDER REGULATORS

BY W. S. MOODY

The sensitiveness of the incandescent lamp to changes in voltage, both with reference to candle-power and life of the lamp, demanded very early in the history of electric lighting a close control of the voltage on constant-potential circuits. With the small direct-current generators that were first used this was easily accomplished by the simple field adjustment of the generator, but when the size of the generators increased and several were operated in multiple, several circuits were usually operated from one station bus-bar. With the low voltage used in direct-current distribution, the feeders could not have a negligible drop; therefore an adjustable artificial loss, in the form of a rheostat, had to be inserted in each feeder and adjusted according to the load. We all remember the early direct-current stations in which these rheostats took up almost as much space as the generators, and consumed enough energy to increase materially the cost of operating the plant. In these rheostats is found the first elementary feeder regulator.

In direct-current practice, boosters, storage-batteries, and other devices have long since replaced this wasteful and unsatisfactory method of control. I refer to such historic methods of feeder control only to show how early in the art there arose the necessity of devising some means of maintaining the desired potential at the center of distribution of each feeder.

When incandescent lamps were first operated by alternating current supplied by high-voltage generators and transformers, the need of feeder regulation did not become apparent, because it was several years before generators of more than 100-kw. capacity were developed; and because attempts at multiple operation of such generators were few and generally unsuccessful. For several years then it was the practice to operate only one feeder from each generator, the desired control of potential being obtained by the field of each generator. With the development of large alternating-current generators, and with improvements in their design and the design of the governors of their prime movers that admitted of multiple operation, there developed the same necessity for the control of individual feeders, operated from high-voltage bus-bars, as had years before been experienced in direct-current distributions.

Given an approximately constant potential on the bus-bars, a feeder may be controlled: first, by a variable resistance in circuit with the feeder; secondly, by a variable reactance in series with the feeder; thirdly, by a variable capacity in multiple with the feeder; fourthly, by a transformer whose primary is in multiple with the circuit, and whose secondary is in several sections, any number of which may be thrown in series with the feeder; and fifthly, by a transformer whose primary is in multiple with the feeder, and whose secondary is in series therewith, and which is so built as to admit of shunting the magnetic flux of the primary.

The first two methods; that is, variable resistance and variable reactance, have been used to only a limited extent. The resistance is objectionable because of the loss of energy and both forms fail in accomplishing the desired result, because they must make the inherent regulation of the feeder worse; that is, the total drop in the feeder is greater than if no such resistance or reactance were in series, and consequently every time there is a change in load, the change in voltage will be greater than if there were no such regulating resistance or reactance in circuit. While therefore with careful attention the desired voltage may, on the average, be more closely obtained by the use of such means of regulation, the variations in voltage will be increased rather than decreased.

Regulation by the use of variable capacity, obtained either from condensers or the leading current of synchronous motors, is possible only on systems having a large inherent reactance. Remarks about this method of control will be deferred until later.

Control by means of a transformer whose secondary is divided into sections, any number of which may, at the will of the operator, be placed in series with the feeder, was one of the first methods successfully worked out for the control of alternating voltage, and has proved one of the most satisfactory. Such a transformer may be readily designed to have as good regulation of its own voltage under varying load as any other transformer, and consequently its introduction into the feeder does not materially affect the inherent regulation of the system. The only engineering problem of consequence involved in the making of this form of regulator, other than the usual transformer problems, lies in the design of a switch that will allow an easy and safe cutting in and out of the various sections of the secondary.

The remaining method; namely, a transformer in which the primary flux may be shunted ordinarily known as an induction type of regulator, can be built to have substantially as good regulation as an ordinary transformer. It does not have a detrimental effect on the inherent regulation of the system, and is particularly adapted for use on circuits carrying heavy currents, circuits that would require expensive and cumbrous switches if controlled by variation of the turns in the secondary rather than by the flux passing through the secondary.

Resistances have been used to such a limited extent that no special form has been developed, and there is nothing, therefore, to describe, even historically. Various forms of reactances, such as simple solenoids with a moving coil or core, or a moving keeper to a U-shaped core, were used to a considerable extent in some of the earlier alternating stations. As the voltage of a series reactance is so far out of phase with the voltage of a high power-factor circuit, the volt-ampere capacity of the reactance must be very large compared with the results obtained, and the inherent regulation of the system is very much interfered with by their use. Compared with their useful work their size is also greatly increased by the fact that the greatest effect is wanted when the current in the feeder is least, so that there must be turns enough to produce the maximum absorption of voltage when the minimum current is flowing. These objections to reactance control are mentioned because even engineers are sometimes surprised at the size of a reactance necessary to accomplish a given amount of control, and also because it is sometimes thought that the transformer with variable flux; that is, the induction regulator, controls by means of its reactance. This, as I shall show later on, is quite an erroneous idea.

Transformer type of regulator. The transformer part of this type of regulator need not differ in any essential particular from any constant potential transformer of the same size and voltage. But some attention must be given to the location of the various portions of the secondary, so that when all the secondary is in circuit, and also when only fractional portions are in circuit, these portions may be located with reference to all of the primary windings so as to have little magnetic leakage, and therefore good regulation. With moderate currents this form of regulator is the most efficient and cheapest, as its construction is that of a simple transformer and only the needed amount of secondary is in circuit at any time. The switch introduces the only complication and limitation in its use.

The difficulty of making a switch that will be durable has been well solved for a current that does not exceed 250 amperes, voltages not above 5,000 or 6,000, and the voltage per step not above 30 to 50.

It is evident that the switch must pass from one contact to the next without directly bridging the intervening space; otherwise one section of the secondary will be short-circuited and so heavy a current will flow as to cause a vicious arc when it is broken, even if the short-circuit is not on for sufficient duration to overheat the windings. When the current does not exceed 150 amperes, or the voltage between steps does not exceed 30, this short-circuit can be avoided in a very simple manner by making the moving blade just a little narrower than that necessary to bridge between contacts, and by providing any form of automatic trip that will quickly snap the blade from one contact to the next. Under these conditions the continuity of the current will be maintained through the arc that bridges the slight break, and the counter electromotive force of this arc will prevent any considerable current circulating in the section of the winding short-circuited by it.

With larger currents, or higher voltages between steps, the arc cannot be depended upon as a preventive against short-circuiting adjacent sections; the moving contact arm must be made in two parts, insulated from each other but joined through a resistance or reactance and connected to the feeder from this preventive resistance or reactance through its middle point. Such reactance or resistance suitably proportioned and connected in this manner will avoid the necessity of breaking any current at a given output of the regulator; that is, the potential generated across the reactance by the flow of the current through it can be made, with a given current, to equal the voltage between steps. Consequently when the blade leaves one of the contacts there will be no difference of potential between it and the terminal that it has left, and therefore no arc. The switch must, however, operate under all conditions of load, and therefore it is not possible to adjust for no arcing except for one definite current. With the best possible proportioning there will be arcing enough gradually to destroy contacts capable of carrying heavy currents when an attempt is made to use this form of switch for heavy duty. When it is desirable to use the switch type of voltage control for these larger currents, therefore, it becomes necessary to use separate contacts for carrying and breaking the current. One excellent way of accomplishing this is to have two electrically operated switches or contactors in series with each half of the rotating switch whose operating circuits are so connected to a small contact device on the main switch as to open the auxiliary contactor and interrupt the current to either half of the rotating switch just before it breaks contact, and again to close the circuit just after it has made contact with any of the various stationary contacts. With this arrangement all the arcing will be removed to the auxiliary contactor switches which may be made very heavy and with easily replaceable contact surfaces. Regulating switches so designed have successfully manipulated 320 amperes with 120 volts per step.

It is evident that the range of control of a feeder regulator can be doubled if the mean of the desired voltages on the feeder or feeders be maintained on the bus-bar, and the regulator used both to increase and decrease this voltage. The transformer type of regulator can be made to operate in this manner by adding to the rotating switch, which enables any portion of the secondary to be thrown in circuit, an auxiliary switch that will reverse the polarity of the primary winding after the switch has been once over its range. The switch required for this reversal is not a difficult one to design, even for quite high primary voltage, since the reversal is made only when the secondary switch is on the zero point of the dial, and when, therefore, there is no current flowing in any portion of the secondary winding. Under these conditions the primary carries only magnetizing current, which, on a regulator of 50 kw. or smaller, is a current easily handled. A typical form of this type of regulator is shown in Fig. 1.

Induction regulators. The induction or magnetic shunt type of regulator differs from the transformer type of regulator in that all the primary and secondary windings are constantly in use. Different types vary the secondary voltage either by moving part of the iron core or one of the windings, or one of the windings and part of the core; the whole or any part of the flux generated by the primary threading the secondary according to the position of the moving part. One of the forms is interesting because of its simplicity, and because of its early development. It consisted of a U-shaped core with a primary winding around the center leg of the core, the length of the primary coil being only about one-third the

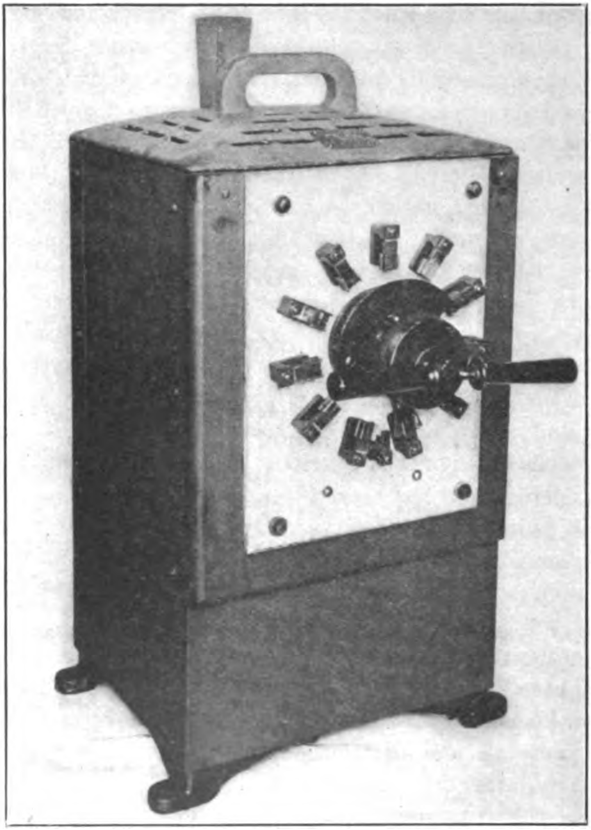


FIG. 1.—Switch type of feeder regulator with reverser.

length of the core. The wire space was long and narrow, so that the portion on the core which projected beyond the primary winding formed an air-gap of moderate reluctance even when an inch or more in width. Concentric with the primary coil was a secondary coil, having the same length of layer, to which the circuit was connected by flexible cables. By means of long screws engaging with nuts on the ends of the secondary coil, the secondary was moved along in the direction of the axis of the core from the position where it entirely covered the primary to a position at the open end of the core. When the secondary covered the primary there was little magnetic leakage, and the full secondary voltage was obtained. As the secondary was withdrawn from the primary, a larger and larger percentage of the flux crossed the air-gap rather than thread the secondary coil, until, when the secondary coil was fully withdrawn, practically all the primary flux was driven across the air-gap in the space between the primary and secondary. A reversing switch in the primary gave the secondary a double range of control. This form of regulator was developed in 1891. It is shown diagrammatically in Fig. 2. A considerable number of these are installed in that historic early transmission of power from Willamette Falls into Portland, Oregon, and are in service to-day. I mention these as being, as far as I know, the earliest successful attempt to build feeder regulators of the induction

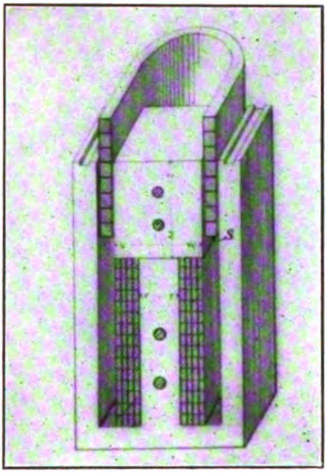


FIG. 2.—Induction regulator with movable coil.

type. This form was somewhat objectionable in that a rectilinear motion of coils or core is always more difficult to arrange for mechanically than a rotating motion; and, secondly, because the air-gap must be large to allow the secondary coils to move through it, consequently the magnetizing current tends to be greater than in other types where the air-gap may be very much less because the moving coils do not pass through the air-gap.

The second type of induction regulator developed had stationary primary and secondary coils located at right angles to each other, and a cylindrical core through which these coils passed. The center portion of the core could be rotated in such a way that any desired part of the flux of the primary coil would pass through the secondary coil.

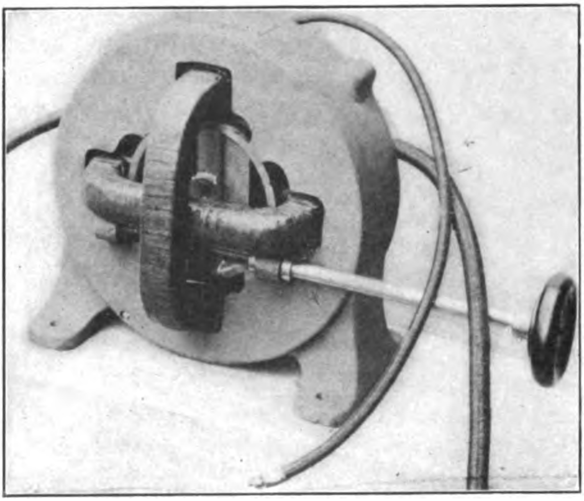


FIG. 3.—Induction regulator with movable core.

This form of regulator, see Fig. 3, is due to Dr. Steinmetz, and was really the forerunner of all the forms of induction regulators that have become so successful and useful. The air-gap in such a construction can be made very small, even less than in an induction motor, because there is no rapid rotation or wear of bearings to provide for, and consequently the magnetizing current need not be greatly in excess of that taken by a transformer with no air-gap. The particular form first developed was limited in its capacity, due to the fact that the primary and secondary were so far from each other that the mutual reactance was high, and inherent regulation consequently poor.

The third form of induction regulator to be developed historically resembles an induction motor in its general construction; the primary corresponds to the field and the secondary to the armature winding of an induction motor, not of the squirrel-cage type, but one with windings that are insulated, the terminals of which are brought out for purposes of control. This form of winding, with its many slots per pole and with only a very slight air-gap, forms a transformer having low mutual reactance between primary and secondary when the moving core and coils are in such position that the axes of the primary and secondary coils coincide. As the core is moved so that these axes are out of line, not all of the primary flux cuts the secondary winding, and the induced voltage in the secondary gradually falls, until, when each secondary coil is midway between adjacent primary coils, there is no voltage induced in the secondary. When the secondary winding is midway between the primary winding, however, it will, if it is carrying current, set up a heavy flux of self-induction which will close itself through the adjacent core between the adjacent primary coils. The result is a poor regulating device except at or near the full load position. This objection was nicely overcome by Dr. Steinmetz, who placed between each primary coil a distributed winding short-circuited on itself, so located that it is cut not by the primary flux but by the secondary self-induction flux just in proportion as the secondary moves away from the influence of the primary flux. Both the regulator with the single coil windings and that with the distributed windings can evidently be used to either raise or lower the voltage by simply rotating the moving core and coil through the angular distance corresponding to the polar pitch.

All forms of regulators so far described have been for use on single-phase circuits only. The distributed winding just described lends itself perfectly, however, to three-phase winding, and is much more efficient in three phase than in single phase circuit, because with the three-phase connection the short-circuited winding may be dispensed with, since the winding of the other phases naturally falls in the same location as the short-circuited winding, and acts with equal effectiveness in eliminating the flux of self-induction in the adjacent secondary.

With a multiphase winding, a secondary coil in one phase, as it passes out of influence of a given primary coil, passes into the field of a primary coil in the next phase. The result is a constant voltage generated in each of the secondary coils regardless of their position with reference to the primaries. The phase relation between this secondary voltage and the phase of the feeder circuit, with which it is in series, however, varies directly as the secondary coil is displaced with reference to the primary coils of the same phase. The result is that while the voltage measured across the secondary remains constant, its effect on the circuit, due to the phase displacement, varies from zero to maximum, and exactly as if the voltage and not the phase relation varied.

Feeder regulators of the induction type have for several years been built in all sizes from 3 kw. to 1000 kw. The larger sizes are seldom used for what could be properly called feeder regulation although some having several hundred kilowatt capacity have been built for the control of high-voltage feeder lines delivering current to sub-stations of several thousand kilowatt capacity. Most of the larger capacity, however, especially those having three-phase windings, are used to control the voltage delivered to synchronous converters, so that the voltage on the direct-current side may vary in accordance with the requirements for bus-bar potential, or for the charging of the storage-batteries used for feeder control and storage purposes.

It is rather interesting to note, in view of the fact that induction regulators larger than 300 or 400 kw. are still quite infrequently called for, that the first induction regulator which was attempted, was built fifteen years ago, and had 450 kw. single-phase capacity.

Automatic control of feeder regulators. A feeder regulator may have ample capacity to compensate for any changes in bus-bar potential or any varying drop in the feeder, and yet the voltage at centers of distributions may be far from satisfactory in its steadiness, due to the inattention of the station attendant or to his inability to change the regulator as rapidly as the variations in bus-bar voltage or feeder losses may require. Moreover, if an attempt is made to overcome this weakness by additional attendants, the increase in operating expenses occasioned thereby may be very considerable.

Many plants now receive current from large power systems, a large part of whose output is absorbed by railway and other motors, whose demands for current vary so rapidly that even if an attendant were constantly watching the voltmeter, in the attempt to adjust the feeder regulator to compensate for the changes in bus-bar potential, he would find it entirely impossible to control the voltage as rapidly as is necessary for good life or good service with incandescent lamps.

It was not, therefore, until about two years ago, when the first successful devices were developed for automatically operating various forms of feeder regulators, that feeder regulators assumed their proper and important sphere in electrical distribution of power.

It will be recalled that various more or less successful attempts have been made in the past to control automatically the potential of generators. The first really successful of these was perhaps the Edison regulator for direct-current generators. The device consisted simply of a rheostat with a special form of rotating arm and contact device moving through a range of only 45 degrees or so, and controlled by solenoids in shunt with the commutator of the machine. It was reasonably successful in isolated plants, put did not admit of satisfactory operation on large plants where the generators had to be operated in multiple.

Various forms of mechanism for automatically controlling the field rheostats of generators have been developed and are used with moderate success, but they are all too slow in their mechanical operation, and many of them too complicated to be extensively used.

In 1891 or 1892 Elihu Thomson made the first attempt to use the only principle of automatic control of generators that has ever proved itself entirely equal to meet all requirements. He met the problem with characteristic boldness of method. Instead of working on a rheostat which must of necessity be slow in operating, he used a series-wound exciter, and brought out two taps from the field winding of this exciter so located that when these taps were joined together a sufficient number of the series turns of the field were short-circuited to give the minimum voltage required to excite the generator under no load. When this short-circuit was removed and the full winding was in circuit the maximum voltage necessary for the excitation of the generator under its greatest designed overload would be generated. He then designed a special form of contact-making voltmeter capable of very rapid response to changes in voltage, and connected the two taps from the field of the exciter to two contacts of the voltmeter. When the voltage was too high on the generator, the voltmeter's contacts would short-circuit this portion of the exciter's field; when it was too low it would remove this short-circuit. Except at no load and full load, of course, there was no position of equilibrium for the voltmeter. It therefore vibrated rapidly, making and breaking the shunt-circuit on the exciter's field, and gave an average voltage dependent on the percentage of time that the contacts were closed or open. The device would undoubtedly have been immediately successful if it had been first tried on a moderate size of generator requiring so small an exciter that an ordinary silver or platinum contact on the voltmeter would have stood up under the constant making and breaking of the circuit. Unfortunately, however, it was tried on an 80-pole, 400-kw. slow-speed single-phase generator. This was a very large machine for those days, and 30 kw. or so were required for excitation. It was found necessary therefore in order to protect the contacts to have an exciter for the exciter, and to operate the voltmeter on the small exciter.

With these three magnetic systems operating in succession there was just enough lag between the operation of the voltmeter and the response in the voltage of the alternating-current generator to make the operation a failure; that is, the voltage of the generator surged over a range of three or four per cent. at a frequency of six to eight cycles per minute. It was not until Mr. Tirrill took up the problem along the same lines several years later that this ideal method of controling the voltage of a generator was successfully perfected.

The Tirrill method differs from the Thomson method only in that the vibrating contact short-circuits a resistance in series with a shunt field exciter, and that the voltmeter is provided with a special alloy of iridium for the contact points; this makes it possible to handle current and voltage quite impossible to handle with any other metal when the circuit is so rapidly made and broken. The wonderful success of the Tirrill regulator in controling all forms and sizes of generators is doubtless well known to us all.

A slightly modified form of the Tirrill regulator has been developed and applied to the control apparatus of feeder regulators, and as a result their value and field of usefulness were immediately increased many fold.

Of all the various forms, the induction type of regulator, free as it is from all moving contacts, lends itself most readily to automatic control. A small motor is readily attached to the same mechanism that is used for hand operation. A switch capable of starting, stopping, or reversing this motor can be easily operated magnetically, and this in turn be controlled by a modified Tirrill contact-making voltmeter. Fig. 4 shows an automatically operated regulator of this type.

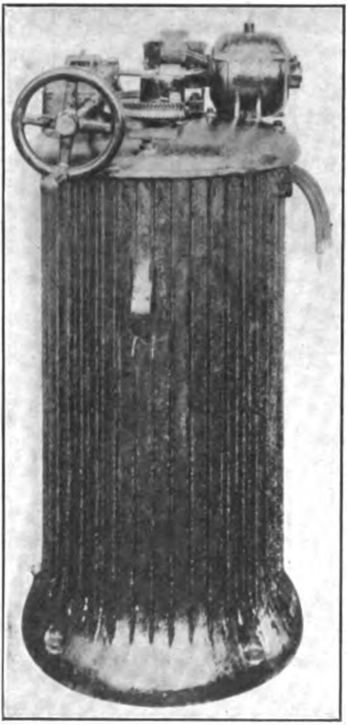


FIG. 4.—Induction regulator with distributed windings, movable core and coils, automatically operated.

When the changes of the voltage of the feeder, due either to varying load or to varying bus-bar potential, are fairly slow, this method of automatic control leaves little to be desired. When somewhat greater rapidity of control is needed, this can be accomplished by keeping the motor in constant rotation and using magnetic clutches whose excitation is controlled by the contact-making voltmeter, thereby saving the time for the motor to come up to speed.

Many feeders have such rapidly varying loads furnishing current to elevators or hoisting machinery, for instance, or they are operated from bus-bars whose potential changes so rapidly, that some form of regulator, in which it is not necessary to move so great a mass as must be moved in the induction type regulator, becomes necessary. Under these conditions one naturally turns to the transformer type of regulator, where the only moving part is the rotating arm of the switch. But the forms of these switching devices which have been previously used offer an almost unsurmountable mechanical difficulty to rapid rotation in the step-by-step automatic snap motion that is required in passing from each step to the next.

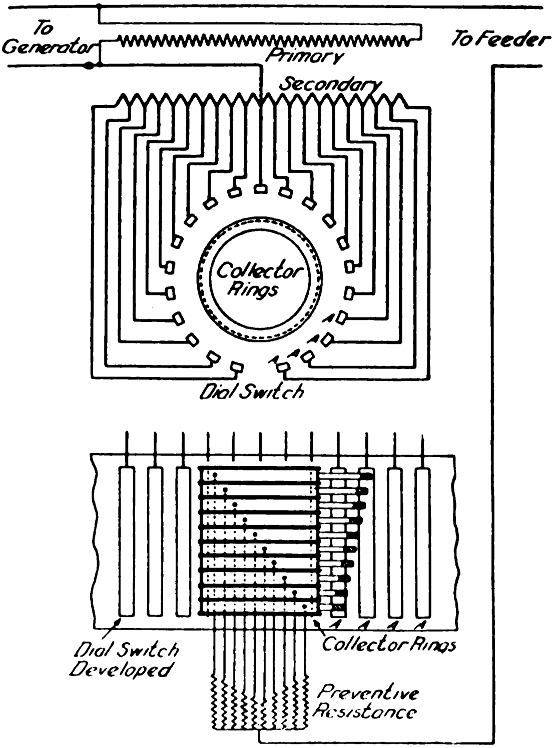


FIG. 5.—Connections of switch type of automatically operated regulator.

A new form of such switch, however, has been successfully worked out in the solving of this problem. The details of this switch will be best understood by referring to Fig. 5, but can perhaps be generally understood from the following description:

The moving element consists of a series of fingers, the majority of which are always in contact with two of the stationary contacts. Each finger is connected to a corresponding stationary collector ring by means of a suitable brush, and each collector ring is connected to the line through a preventive resistance. The individual fingers do not span the spaces between the adjacent contacts, but the arrangement of the combination is such that when the center of the top finger is on the center of one contact, the center of the bottom finger will be on the center of the next contact, the intermediate fingers being spaced so that the centers of all are on a straight line, joining the upper and lower fingers. The resistances which connect the several fingers to the line not only prevent excessive exchange currents as the fingers pass from contact to contact, but cause the change in the secondary voltage to be gradual rather than in steps. The moving member may therefore be left in any position whatever, and a much closer adjustment of voltage is obtained than by the switch which passes in one movement from each step to the next.

The moving parts of this form of switch can be made so light and compact that a very small motor, acting through suitable gearing, will move it from rest round the entire circumference of the contact points, covering the entire range of control of the regulator in from two to three seconds. Such a device, operated from a constantly revolving motor by means of the magnetic clutch and the rapidly vibrating contact-making voltmeter, cannot, of course, forestall needed changes in voltage, but it comes about as near doing so as can be imagined when parts having any appreciable mass are to be moved. Fig. 6 shows two simultaneous charts, the first showing the line potential and the second the feeder potential after having been regulated by this type of regulator. We find that with such a device, a source of varying potential which no one would think of using for any other purpose than the operation of motors, becomes available to give entirely satisfactory incandescent lighting service.

So far no attempt has been made to develop this form of regulator for handling much more than 150 amperes. The slight wear that must take place on the rapidly moving parts, and the generally increased complexity of the mechanical parts, makes it desirable to use the induction type of regulator for automatic work whenever it will fill the requirements as to speed; where it will not fill these requirements there need be no hesitancy in making use of the more sensitive rotating switch type, provided the work comes within the range of its capacity. Fig. 7 shows a regulator of this type.

Just a few words as to how the automatic regulator may be adjusted to give constant potential at the center of distribution rather than at the station. The first method that would probably occur to any one would be to bring back from the center of distribution potential wires which would be connected to the terminals of the contact-making voltmeter. This is not so simple or satisfactory as it might seem, for the expense of running the wires is by no means negligible, and unless they are carefully crossed to avoid induction, current in the feeders might

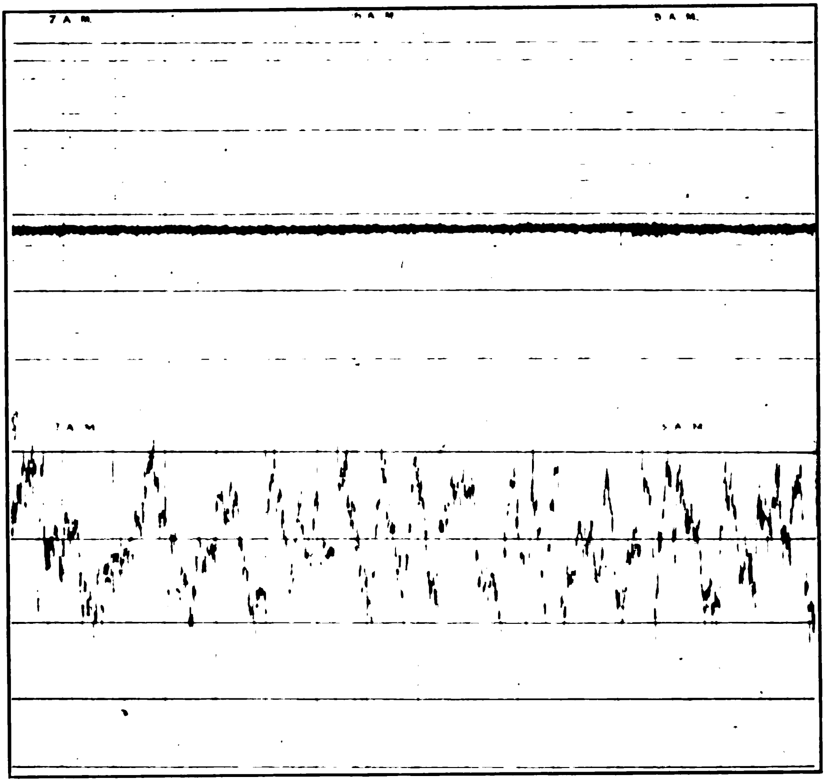


FIG. 6.—Charts showing the operation of the automatic switch type of regulator.

induce sufficient voltage to make the voltmeter's operation quite inaccurate. A simple means of accomplishing the result, which is often all that is necessary, is to have on the winding of the contact-making voltmeter an auxiliary winding connected to the secondary of a suitable current transformer, whose primary is in series with the feeder. If the windings of current transformer and voltmeter are properly proportioned and connected so that the current from the current transformer opposes the current in the shunt coil, the voltmeter will become differential in its action to any desired extent and will cause the feeder regulator to give a voltage which will increase the voltage across the feeder in proportion to the drop in the feeder. This simple method will, however, only increase the voltage in proportion to the current in the feeder. But this is not all that is necessary, as the drop in the alternating-current feeder is not only proportional to the current it is carrying, but is also roughly inversely proportional to the power-factor of this current. To

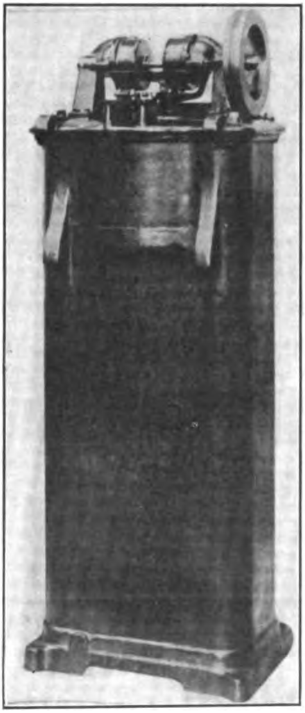


Fig. 7.—Automatically operated switch type of regulator.

obtain constant potential at the center of distribution under all conditions of load, therefore, it becomes necessary to feed the differential winding of the voltmeter from a source of voltage that will be proportional to the voltage lost in the feeder under all conditions. This is nicely accomplished by a device commonly known as a line drop compensator, which consists simply of adjustable reactance and resistance placed in series with the secondary of a current transformer placed in the feeder. By adjusting the reactance and resistance in this device so that they bear the same relation to each other as do the reactance and resistance of the feeder to be controlled, a source of voltage which will give the desired effect on the differential winding of the contact-making voltmeter will be obtained, and absolutely constant potential will be maintained at the center of distribution under all conditions of current and power-factor.

The improved quality of the service which can be given when suitable automatic potential regulators are made use of, and the increase in the life of the incandescent lamps which results therefrom, should be sufficient inducement to make the installation of automatic control well-nigh universal. There is perhaps a more direct effect accomplished by their use which would appeal more strongly to many station managers, simply because the economies resulting are more evident. I refer to decreased station attendance.

The time is fast coming when nearly all service feeders will emanate from sub-stations rather than generating stations, these sub-stations being supplied from either distant water powers or great steam generating stations. In fact, a large proportion of electrical power is so distributed already. Such stations frequently have no rotating machinery, and if they do it is usually of so simple a character that it needs very little attention. Watching the voltmeter on the various feeders, and adjusting the feeder regulators, therefore, becomes almost the sole work of the attendants in such a sub-station.

One attendant can satisfactorily watch only one voltmeter, and adjust one feeder regulator at a time, and therefore if reasonably good service under varying load or varying potential received at the sub-station is to be accomplished, it is necessary to have an attendant for almost every feeder, and even then the service may be very poor. It is in eliminating the necessity of these attendants, therefore, that the greatest direct economy can be accomplished by automatic regulators.

DISCUSSION ON "ALTERNATING-CURRENT FEEDER REGULATORS." TORONTO SECTION, FEBRUARY 20, 1908.

(*Subject to final revision for the Transactions.*)

R. G. Black: We have used regulators of all the types described and have found them to give good results in practical operation. The automatic regulator is particularly interesting inasmuch as it keeps the voltage at the centre of distribution constant and takes a great deal of work off the station operator.

I am sorry that Mr. Moody did not discuss the relative merits and disadvantages of several other types of regulators; for instance, a type consisting of a transformer, the low-tension side of which is in series with the line and the high-tension side energized from an auto-transformer placed across the line. By means of taps brought out from the autotransformer, the voltage on the primary of the series transformer is raised or lowered and the regulation thereby effected without breaking the heavy current which is flowing in the circuit. In this way a gradual raising or lowering of the voltage may be effected, and it is the writer's opinion that there will be very much less wear at the shifting contacts. However, there may be other disadvantages which more than counterbalance this feature.

The ease with which a feeder regulator makes it possible to regulate a number of alternating-current circuits, from one bus-bar stands out in great contrast with the low-tension, direct-current system, which necessitates having two or more sets of bus-bars each energized by separate generators and then switching devices to transfer the feeder from one bus-bar to another.

J. Kynoch: A large number of lights and some motors were required in a large building, and the only available source of supply was feeder to a suburban railway. It was found that the voltage at the end of this feeder varied from 350 to 575. It was proposed to use a direct-current motor-generator set, the motor being wound for 500 volts normal, and the generator for 220 volts. In order to keep the speed of motor and voltage of generator constant, a Tirrill regulator was arranged to be placed on the fields of each machine, the relays on the motor fields being so connected that as the voltage of the railway feeder changed the field strength of the motor would be varied, and in this way the speed kept constant. The only other requirement was that the design of the motor should be such that the motor should be capable of giving the required output at the minimum voltage for such length of time as such low voltage may exist.

The regulator on the generator was applied in the usual manner and was arranged to give either constant terminal voltage at the generator or a constant voltage at the end of main lighting feeder. In this way an eminently satisfactory control of voltage was obtained from a source which under ordinary circumstances would be quite impracticable for incandescent lighting.

Another way to meet the above conditions would be to apply a Tirrill regulator to the generator fields only, and allow the motor speed to vary with changes in feeder voltage. This, of course, needs a specially designed generator to give the normal voltage at minimum speed, and also means using a field rheostat of very high resistance, in order to reduce to normal the high voltage at maximum speed.

Mr. Moody refers to the possibility of voltage regulation by using capacity such as the leading current from synchronous motors. I should like to enlarge upon this as follows: The voltage regulation of alternating-current power feeders having considerable reactance can be accomplished by applying a Tirrill regulator to the exciter of a synchronous motor connected to the ends of such feeder. In this way not only practically constant potential can be maintained but also high power-factor due to the regulator varying the excitation of the synchronous motor and thus causing the same to supply leading or lagging current as the voltage of the circuit drops or increases, respectively.

This scheme is especially valuable on 60-cycle transmission lines as the inductive losses on such lines are usually considerable, and consequently the line regulation is very much worse than on a 25-cycle circuit carrying the same class of load. Of course, in order for a motor successfully to regulate a transmission line, it would be necessary for the motor to carry a reasonable proportion of the load, probably in the neighborhood of 30 per cent., but a larger proportion would be better. It is, of course, assumed that Tirrill regulators would be connected to the generators at the power station, so that the motor would not have to do an abnormal amount of regulation.

R. S. Kelsch (by letter): One Canadian company has a number of induction regulators in service, some of which have been in operation almost ten years. These regulators vary in size from 40 kw. to 800 kw. capacity each. There are a number of 40-kw. oil-cooled regulators used in connection with synchronous converters and several 40 kw. air-cooled regulators used in connection with three-phase feeders. The company also has two 350-kw. air-cooled and one 800-kw. three-phase regulators used in connection with sub-station work.

In the sub-station, the power is received at a voltage which varies according to the demand made by the different sub-stations on the line. In one instance the power is received at approximately 11,000 volts stepped down to 2300 volts. This pressure is used for power service. For the lighting load, the same power is delivered to a second bus-bar through a 350-kw. regulator, which automatically maintains the voltage required, depending upon the load on the lines.

The 40-kw. regulators are used for individual feeders, where the load varies considerably. For example: the company has a feeder three miles long, which, during the day time delivers power to a large induction motor for pumping purposes. The load on this line varies during the 24 hr. from 10 to 100 per cent. and the power-factor changes from 80 to 95 per cent. It would be impossible to handle this business without induction regulators.

In one of the sub-stations, 14,000 h.p. is received and a large portion of the power distributed locally, the balance distributed to a considerable distance. The same pressure would not suit both purposes, but the 800-kw. induction regulator makes it possible to receive a pressure suitable for local distribution, and, at the same time, transmit the balance of the power a considerable distance, delivering it at the required pressure.

During the ten years these regulators have been in service there has not been one accident, failure to work, or interruption of any kind due to the regulator, notwithstanding the fact that most of the regulators are exposed direct to the line.

DISCUSSION ON "A TRIGONOMETRIC METHOD FOR THE SOLUTION OF ALTERNATING-CURRENT PROBLEMS." ATLANTIC CITY, N. J., JULY 2, 1908

(Subject to final revision for the Transactions.)

Comfort A. Adams: Eight or ten years ago I worked out, for the purpose of transmission line calculations, a method which, with tables and curves, was an almost exact equivalent of Mr. Pender's method. If one had frequent occasion to make transmission line calculations these tables and curves would be a great assistance, but for infrequent use it takes longer to become familiar with the method than to solve the problem by the long way.

Moreover, I cannot help viewing a matter of this sort from the standpoint of the teacher, and from that standpoint it seems to me that these short-cut methods are undesirable since they do not bring out step by step the physical meaning of the problem; they do not keep one reminded of exactly what one is doing, and an error is less likely to be detected. The natural method has proved more serviceable in my own work, where a given type of problem is considered occasionally, and I think it far more valuable for students. However, I do not wish to minimize the value of any such labor-saving device, as it has a legitimate field where it serves a most useful purpose.

W. A. Del Mar (by letter): The treatment of alternating-current problems has been subject to rapid evolution. When Dr. Steinmetz's method of imaginary quantities appeared it seemed that the summit of development in that line had been reached, but Mr. Pender's method is as great in advance of the Steinmetz method as the latter was of the plain vector method which preceded it. It is a more important advance than that due to Steinmetz's method, because it places the solution of alternating-current problems within the reach of those of very limited mathematical training.

To the teachers, Mr. Pender's method should particularly commend itself, as it can be quickly acquired and students can be taught the solution of alternating-current problems before they reach the fairly advanced mathematics. One effect of this would be the possibility of inculcating elementary ideas about alternating currents before the professor of mathematics had propounded the theory of vectors and imaginary quantities.

A preliminary reading of the new method gave the impression that for didactic purposes it would suffer from the disadvantage of not offering a direct physical understanding of the various operations. This impression soon vanished, however, when the ease of working became apparent, for the observations of the writer have led him to believe that only a small portion of technical graduates understand the theory of alternating-current machinery so that they can apply it to the solution of practical problems. This condition arises either from indifference to mathematics, or from the ease with which the subject is forgotten in after years. The simplicity of Dr. Pender's method overcomes these two difficulties in an admirable way.

The writer has had occasion to try the new method to solve a number of problems, including the eddy-current brake and transmission problems, and has found the application extremely simple in every case.

L. W. Rosenthal (by letter): I should like to point out the character of the error resulting from the approximation for E_0 between formulas (17) and (18). Denoting the power-factor angle of the load by ϕ and that of the line by θ, the error will depend on $(\theta+\phi)$ for leading currents and on $(\theta-\phi)$ for lagging currents. The error also depends on the per cent. voltage loss. The attached curves show the correction which must be applied to the approximate values of D, from which it is evident that for the range of 0 to 20 per cent. loss the approximation is sufficiently close only to about 45°. The values of $(\theta-\phi)$ for

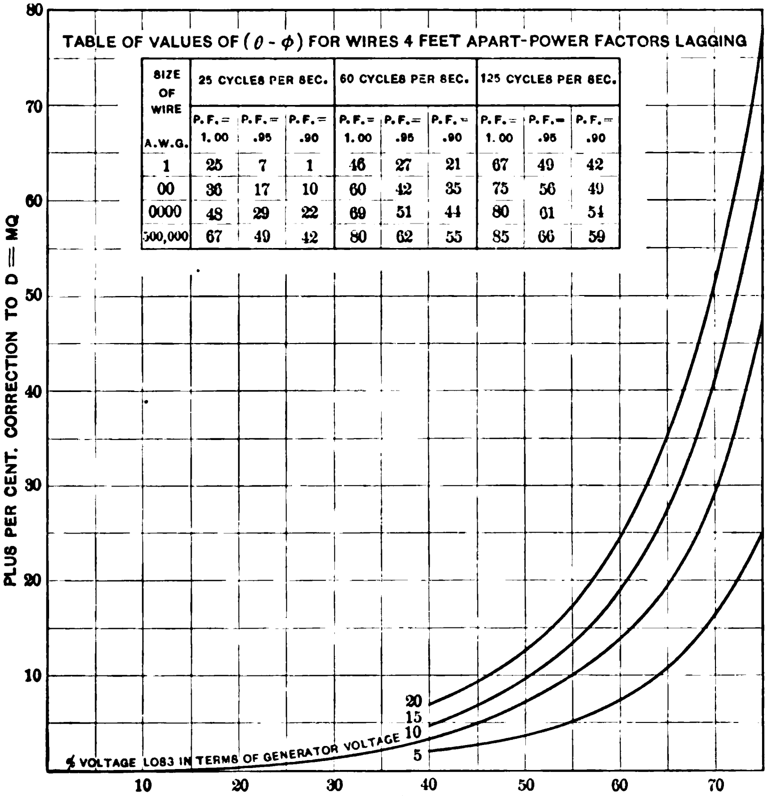


TABLE OF VALUES OF $(\theta - \phi)$ FOR WIRES 4 FEET APART-POWER FACTORS LAGGING

SIZE OF WIRE	25 CYCLES PER SEC.			60 CYCLES PER SEC.			125 CYCLES PER SEC.		
A.W.G.	P. F. = 1.00	P. F. = .95	P. F. = .90	P. F. = 1.00	P. F. = .95	P. F. = .90	P. F. = 1.00	P. F. = .95	P. F. = .90
1	25	7	1	46	27	21	67	49	42
00	36	17	10	60	42	35	75	56	49
0000	48	29	22	69	51	44	80	01	54
500,000	67	49	42	80	62	55	85	66	59

FIG. 1

various wires, frequencies, and lagging power-factors are shown in the table on Fig. 1.

As an extreme case of the possible error, suppose in the first numerical example that the frequency be taken at 125 cycles per second, the power-factor at 100 per cent., and the load reduced to 3500 kw. in order to obtain about the same voltage loss. The exact formula (17) will then give a voltage loss of 21.8 per cent., while the approximate formula (18) shows a loss of 12.8 per cent. In other words, the "approximate value" requires a correction of 70 per cent., as is also shown by the curves at 75° and a loss of 18 per cent. of the generated volts, corresponding to 21.8 of the received volts. In the example chosen by the author $(\theta - \phi)$ equals 17°, and hence the error is small.

Although the author has drawn attention to the increasing error of the approximation by the letters *a*, *b*, and *c* in Table III, yet it would have been better to omit the values below *c*, which approximately correspond to $(\theta \pm \phi)$ equals 40°. It seems, therefore, that for high frequencies or power-factors, and for large wires or per cent. voltage losses, the approximate formulas (18) may give erroneous results. They should not be used in any case where the drop-factor M is below the c of its column.

DISCUSSION ON "NOTES ON THE ELECTRIC HEATING PLANT OF THE BILTMORE ESTATE." ATLANTIC CITY, N. J., JUNE 29, 1908

(Subject to final revision for the Transactions.)

Percy H. Thomas: This paper is a little out of the ordinary, but the subject which it treats is well worth the attention of light and power men, as indicating how under certain conditions additional load may be gotten. I think the main lesson to be taken from what Mr. Waddell says, is that it is necessary to treat such matters as engineering problems when dealing with electric heating on a large scale, just as in the case of the boiling of water on a large scale in steam-electric plants. The heating of tea kettles and curling irons can be handled satisfactorily without special engineering training, but when large quantities of water are to be heated by electrical means of any kind it is necessary to treat the case as an engineering problem.

Elmer A. Sperry: Will Mr. Waddell please give us the details of his flash boiler?

Charles E. Waddell: The boiler is made of five 3-inch pipes, each six feet long; around each pipe a heating element is wound. The elements are externally protected, and thermally insulated, with metal jacket and dead air space. All five tubes connect together at the top, forming a steam header. Water, from the hot water system, enters at the bottom of the tubes, the quantity admitted being controlled by an automatic regulator the function of which is to maintain the water-level at a fixed point. The boiler is also provided with a low-pressure safety-valve, the discharge from which is conducted into a nearby waste pipe. In operation the device is cleanly, noiseless, and automatic.

John H. Finney: At what price must current be purchased in order to compare with fuel—anthracite coal, for instance?

Charles E. Waddell: Tests on the large steam heating boilers at Biltmore have demonstrated that under normal working conditions their efficiency is about 50 per cent. Assuming that a pound of anthracite coal has a theoretical heating value of 14,000 B.t.u., and allowing an efficiency of 50 per cent., the effective value would be 7000 B.t.u. A kilowatt-hour is practically 3500 B.t.u., and hence a kilowatt-hour is equivalent to two pounds of coal, assuming of course, that the kilowatt-hour is delivered at 100% efficiency.

Anthracite coal with us costs from $10 to $11 per long ton, virtually one-half cent a pound. To be on a parity, two kilowatt-hours would have to cost one-half cent, hence at a rate of one-fourth cent per kilowatt-hour.

Taken on the whole this is not altogether a fair comparison; for while it establishes the physical equivalent under working conditions between fuel and electrical energy, it does not take into account the time-element and stand-by losses, both of which are important factors in the economy of any plant.

Where the actual use of heat is a small percentage of the total time, entailing as a consequence large stand-by losses; where the service is intermittent; or where the fuel plant is small and the item of attendance large in proportion to the service, the cost of electricity could easily be two or three cents per kilowatt-hour and still effect economy.

To compete successfully with fuel in plants of magnitude—our house heating plant for example, where the steam boiler capacity is some four hundred horse power—electrical energy at from three to five mills per kilowatt-hour would in all probability be equivalent to coal at $10 per ton.

DISCUSSION ON "THE RELATIVE PROPORTIONS OF COPPER AND IRON IN ALTERNATORS." ATLANTIC CITY, N. J. JULY 2, 1908

(Subject to final revision for the Transactions.)

W. L. Waters: Mr. Fechheimer is to be congratulated on the success obtained in his attempts to reduce the design of alternators to a series of mathematical formulas. A good many attempts have been made in the past to reduce electrical machine design to an exact science, but they have met with little success. The first attempt was made in regard to transformer design, when rules for the most economical dimensions were formulated by various engineers, but even in this extremely simple case such rules met with very little success. I think that such attempts only serve to emphasize the well known statement that electrical machine design is an art and not an exact science.

In the case of an alternator, there are many variables, such as voltage, speed, and frequency, which make radically different designs necessary, and these different designs may again introduce further complications in regard to cooling and windage of the machine. This being the case, it is not surprising that Mr. Fechheimer finds such extreme variations in his constants.

I think this paper is more useful in an academic way than as an assistance in practical designing. The probability is that for practical commercial designing we shall find it necessary to keep to our old method of trial and error, basing our designs and changes in design on past experience. Mr. Fechheimer will no doubt find that so much latitude must be allowed in fixing his constants that his method will in the end practically amount to a trial and error method, similar to that which has been in use for the last fifteen years.

Comfort A. Adams: While there is undoubtedly much truth in what Mr. Waters says, there is, on the other hand, no doubt as to the very great usefulness of a general analysis of design problems carried out as indicated in Mr. Fechheimer's paper. This is particularly true in the case of a new line of machines where the limitations introduced by the necessity of employing old frames or stampings are absent; but even in many other cases the general analysis reduces the amount of the cut-and-try process and renders the work of design more rational. Designing engineers are too much inclined to assume, because their machines operate satisfactorily and are reasonably successful commercially, that they cannot be improved. That this is far from true in many cases would, I feel sure, be made clear by the application of just such methods of analysis to machines which are the results of years of the cut-and-try process. Of course, as Mr. Waters intimates, a vast amount of practical experience and judgment is necessary to produce a good commercial piece of apparatus; but can there be any doubt that the more rational, scientific, theoretical, general analysis of this sort, when illumined by the same experience and judgment, will give better results than the experience and judgment alone? The claim often made by the practical designing engineer that he has no time for such careful theoretical analyses can hardly be upheld by experience. To me, the obvious fact is that the designing engineer cannot afford to omit the consideration of any point of view which tends to make more perfect the product of his work. Who has not had the experience of pushing through a hurry-up job, only to find that the saving of a few hours or even of a few days has cost the customer weeks or months of delay and consequent loss, and the manufacturer heavy financial loss, due to changes made in the finished product which might have been made in the design.

DISCUSSION ON "PRIMARY STANDARD OF LIGHT." ATLANTIC CITY, N. J., JULY 2, 1908

(*Subject to final revision for the Transactions.*)

W. S. Franklin (by letter): The establishment of a reliable and reproducible light standard is of very great importance, and we naturally look to our Bureau of Standards to carry out such researches as may be necessary for its realization. I therefore move that the Bureau of Standards be requested by the Institute of Electrical Engineers to undertake such researches as may be necessary to determine the practicability of the light standard suggested by Dr. Steinmetz,[1] and, to develop such a primary standard of light if it be found practicable.

In asking the Institute to place itself on record in this matter, I must say that as it seems to me Dr. Steinmetz's proposal cannot be a complete solution of the problem. Indeed, I do not believe the problem is capable of complete solution. Our present ideas of precision, and the theory of errors of observation as it stands at present, have been developed almost wholly in connection with extremely precise measurements, such as measurements in astronomy and geodesy, where the thing which is measured approximates very closely to an actual "state of permanency," that is, where the thing which is measured actually exists as an unvarying physical condition. In attempting to establish a standard of light, however, it is important, as it seems to me, to understand that the present ideas of precision of measurement are in many cases inapplicable. Measurement in its most general aspects consists in bringing two things or systems into a kind of congruence, and all errors of observation originate in the incompleteness of this congruence test. In view of this general statement it is possible to distinguish two classes of errors of observation, namely, (a) errors which are due to erratic variations in the thing or system which is being measured, and (b) errors which are due to erratic variations in the measuring devices. The former being inherent in the thing which is measured, may be called *intrinsic errors*; and the latter, being outside of the thing which is measured, may be called *extrinsic errors*.

The probable error of a result, in so far as it depends upon extrinsic errors (irregularities in the measuring devices), is a measure of precision in the ordinary sense of that term, whereas the probable error of a result, in so far as it depends upon intrinsic errors (irregularities in the thing or system which is being measured), is a measure of the degree of indefiniteness of the thing which is measured.

It is generally possible to distinguish between extrinsic errors and intrinsic errors, and it is desirable to use the term *probable error* (as calculated from extrinsic errors) as a measure of precision, and to use the term *probable departure* for that part of the probable error, ordinarily so-called, which depends upon intrinsic errors.

---

[1] PROCEEDINGS American Institute Electrical Engineers, March, 1908, p. 297.

In order to make these ideas perfectly clear, let us consider a particular case of measurement relating to erratically[2] varying conditions. For example, let us consider the repeated measurement of the current which is delivered by an electric railway power station. The successive measured values of the current differ greatly from each other, and one might proceed in the ordinary way in the determination of the "probable error" of the result. Suppose, however, that the ammeter is carefully studied by measuring with it a very carefully controlled current output which is kept as nearly constant as possible. In this way the systematic and erratic errors of the ammeter may be determined, and the probable error of an ammeter reading under these conditions would be a measure of the precision of the instrument. Let a be the probable error of a single observation of the ammeter, so determined. Let A be the probable error of a single reading of the ammeter as determined from the residuals of the observed values of the current output of the station. Then $A^2 - a^2$ is the probable departure of the current output of the station at any given instant from its mean value, that is to say, the difference between the mean value of the current output of the station and its actual value at any instant is as likely to be greater than $A^2 - a^2$ as it is to be less than $A^2 - a^2$.

Suppose the value of a in the above discussion to be one ampere and the value of A to be ten amperes. Then it is evident that the extrinsic errors (due to irregularities in the measuring device) in the above measurement are entirely negligible in their effect on the result as compared with the intrinsic errors (due to irregularities in the system which is being studied).

Ordinary photometry presents a case in which intrinsic errors are very great because the actual intensity of light sensation depends upon so many varying conditions which are beyond control; in fact, the intensity of the light sensation which is produced by a given beam of light depends upon manifold individual peculiarities of the person, upon the degree of fatigue of the retina, and upon the degree to which the sensation is enhanced by attention, to say nothing of variations in composition of the light (relative intensities of the various wave-lengths which are present). It would therefore seem to be hopeless and indeed meaningless to attempt to establish a unit of light which would be completely definite except in so far as the physical character of the light is concerned. The proposal of Dr. Steinmetz does, in fact, seem to provide for complete definiteness of the light unit from a physical point of view, and the degree of precision with which this light unit might be reproduced would probably be so great as to leave nothing to be desired, considering the very great intrinsic errors in photometric measurements.

---

[2] Any set of varying conditions must be thought of as erratic when no attempt is made to analyze the varying conditions into systematic groups. Thus the variation of current output of an electric railway power station is to be thought of as erratic unless an attempt is made to study the mean daily and hourly fluctuations of load. For the present purpose, the current output of such a station is assumed to be erratic.

Carl Hering: I have been very much interested in this paper by Dr. Steinmetz, and am very glad to see a suggestion, in a practical form, of a new unit of light, based on the power equivalent. It interests me personally, because I have for a number of years (since 1901 or 1902) recommended that our unit of light should be based on the power unit, that is, that the unit of light should be defined as the light produced by one erg per second converted entirely into light.* But I suggested no specific way in which that could be carried out practically other than to base it on one selected wave-length, or on a certain average wave-length, and I am therefore very much pleased to see that Dr. Steinmetz has offered this very interesting and apparently possible solution.

There is another reason why it is desirable to use the power unit in which to express our unit of light. We have at present three groups of units, the absolute (or electrical) units, the gravitational units, and the heat units. All of our units, except those of light, can be referred to one of these three. They have as connecting links the mechancial equivalent of heat, the acceleration of gravity, and the specific heat of water. Each of these three groups of units was originally started on an entirely independent basis, and the connecting links had to be derived afterwards by experiment. We have at present a unit of light which does not belong to any of these; it is based on an entirely new foundation, and it will be necessary to find by experiment the connecting links with these three groups of units. Dr. Steinmetz's suggestion is not to form such a new group, but to start by making the unit of light coincident with one of the existing groups, namely, the electrical or absolute units.

The term " unit of light ", used throughout Dr. Steinmetz's paper, might be confused with the term " candle-power " by those who have not paid particular attention to the subject of light units. Of course, he does not mean candle-power, he means flux of light, as he stated in his abstract. There is evidently no possibility of an equivalent between watts and candle-power. The only equivalent can be between watts and flux of light. Flux of light is equal to candle-power multiplied by a solid angle, or to illumination multiplied by a surface.† We use the term " watts per candle-power "--but, of course, that is well known to be an irrational expression, although it has come into our nomenclature. We mean, of course, watts per spherical or hemispherical candle-power.

I call attention to an error in the diagram of the musical scale, in which the " a " to the left should be " e." I suggest that the English equivalents be added to this musical scale, as it will then be more easily understood by English readers; Dr. Steinmetz has apparently adopted the German nomenclature. Why does he reverse the conventional methods in the diagram by having the shorter wave-length to the left and the longer wave-length to the right, instead of the reverse, which is the universal method in musical practice; also in showing the spectrum in which, I believe, it is conventional to show the red end to the left and the blue end to the right. There is an error in the text a little further on: one tone represents 60 deg., not 30 deg.

---

* See Conversion Tables, Hering, p. 3; also p. 147.

† See Conversion Tables, Hering, p. 147.

At the close of the paper, Dr. Steinmetz says that any color can be made up of these three. I am interested in knowing whether he is really quite sure of that, for the following reason: If we take three colored pigments and mix them together, we will get a certain color; now if we take some of that mixed pigment, and mix with it some white pigment, and then take some more and mix with it some black pigment, we will have, with the original mixture, three distinct colors. Each one of them will have the same relative quantities of the three original colored pigments in it, and yet it will in itself be an entirely different color from the other two. It might be said that they are shades of the same color. Now the question is, whether a parallel to this exists in the mixing of light rays. That is, is there in the mixing of light rays, something which corresponds to the admixture of white pigment or black pigment to a colored pigment?

Some years ago, when I was interested in this subject of the equivalent between power units and light units, I was desirous to know about what the magnitude of that unit would probably be; that is, what the conversion factor between light and power would be. I found some determinations made quite a number of years ago and after recalculating them to bring them to our present units, I found the figures to be 5.3 spherical candles per watt.* That figure might be termed the electrical equivalent of light. Hence, if the original tests were correct (I took them as I found them and am not responsible for their correctness), the figure will be about of that magnitude, which corresponds to 0.188 watt per spherical candle-power. If this figure be correct, that would be the ultimatum which we will ever be able to reach, as it would mean an efficiency of 100 per cent.

The unit which Dr. Steinmetz proposes naturally involves the solid angle when reduced to candle-power, and we therefore have the choice now in defining that unit, of selecting either the steradian (or absolute unit solid angle) or the sphere, as the solid angle to be included in that unit. Selecting the sphere eliminates the troublesome 4π from most of our calculations of light flux, which are made in spherical candles, and are not based on steradians.

---

* Mechanical Equivalent of Light, Hering, *Elec. World*, April 20, 1901, p. 631.

Clayton H. Sharp: I would like to submit that when any member of this Institute is going to present to us a general solution of the electric circuit and the general solution of the perhaps equally difficult problem of the standard of light, he should at least give us a chance to catch our breath in between.

It looks to me as if this were, in a way, a general solution of this problem. The whole question of the standards of light, the history of the subject, shows how difficult the problem has been. For many years the flame standards were used, and were sufficiently good for the purpose. With the introduction of electric lamps, which were capable of more accurate measurement, a greater precision in photometry was at once demanded, and certain fundamental difficulties which exist in flame standards became known for the first time.

As a solution of the question of a more reliable standard of light, Violle came to the front with his propositions, namely, the use, as a standard, of the light emitted by a square centimeter of platinum at its point of solidification. This proposition, being on the face of it very attractive, was received and adopted at several electrical congresses, but it has never been found feasible to put it into practical operation, because a sufficiently accurate reproduction of this so-called " absolute " unit of light could not be carried out. Other propositions have been made of a similar nature, and the proposal to use energy measurements is not a new one. We find that Lummer made an extensive investigation of a standard of light which was defined in this way: the standard light shall consist of the luminous radiation from a surface of platinum brought to such a temperature that the ratio of the radiation which it will transmit through a certain cell containing water to its total radiation per unit surface is as 1 to 10. Now, it should be theoretically possible to define a standard in this way. The great difficulty with such a definition, however, is that it involves the measurement of the ratio of the intensities of radiation, one of which, at least, is very low. Another difficulty with it is that it depends upon the radiating properties of a certain substance, namely, platinum. This latter difficulty might be obviated by using, instead of the platinum surface, a surface of a theoretical black-body. However, the first difficulty would remain, and it seems to be of sufficient importance to preclude the possibility of establishing an accurate standard in this way.

The proposition which is made to us to-day appears to be the very first one which offers a chance of the establishment of a standard of light based on energy measurements, and independent of the properties of any substance whatever. Not only does it offer us a standard of light, but it gives us also the possibility of a standard for the measurement of colored light also, since a variation of the proportions of the different colors used will produce a variation in the resultant tint. The latter feature may very well be one of considerable importance in view of the ever-increasing diversity in tints of the lights that we have actually to measure in the photometer room.

As Dr. Steinmetz has said, we have to deal here with a physiological effect, and not with a purely physical effect. Ordinarily, the physiological effect which we get from an incandescent lamp, or from most of our light sources, is an effect made up of the various wave-lengths of the spectrum; in other words, the spectra of our common light sources are continuous spectra, and have difference in color on account of a continuous difference in the ratio of the intensities of the various wave-lengths.

It is to my mind an open question, one which must be submitted to experimental determination, whether we shall get ultimately the same effect from the admixture of three monochromatic lights that we should get from a polychromatic source; whether it is not possible that minor differences in the sensibility of individual eyes to the different colors will not become much more apparent when we measure a polychromatic source against a source which is made up of three colors, than we get when we are mesauring two polychromatic sources, one against the other. Will the physiological effect of three colors mixed together in all cases be the same as the physiological effect of all the colors mixed together, though in varying proportion?

In regard to the difficulty of the actual energy measurements which are involved in the realization of this solution of the standard of light, it seems to me, while they are very considerable, yet they are not necessarily insuperable, because it is not necessary, as I understand it, to deal with any extremely small quantities of energy. There is no reason why the sources which are used for the production of these three lines should not be sufficiently powerful so that there is no small concentration of energy in each of the lines and so that it will become physically possible to measure the radiation-intensity of each of these lines with a sufficient degree of accuracy for the purpose. I think there is no doubt that the method ought to be given a very thorough trial indeed, and I think also that the place where it ought to be tried and investigated is at the Bureau of Standards, at Washington, where the answer to the question can be found, if it can be found anywhere.

I think there was some confusion in the statements of the last speaker in regard to the nomenclature of this matter. As I understand it, Dr. Steinmetz's proposal looks to the production of a standard illumination on a given surface. Now, illumination is not the same thing as candle-power, though it can be referred to the theoretical point-source of light placed at a certain distance from the surface which is illuminated. Neither is illumination simply flux of light, but it is flux of light per unit area, or flux density, and consequently the proposition is to produce, really, a standard illumination on a surface, and if we wish to refer that to an imaginary point-source of light, which really does not exist in the experiment, we can say that illumination is produced by a source of one candle-power. However, the solid angle does not enter into the question directly, neither necessarily does the candle-power enter into the question directly, nor does the 4π come in. It is a question simply of producing a unit or standard illumination on a given surface, or unit flux density, or unit flux per unit area; for when we get right down to the fundamentals, it is flux we have to deal with in the case of light. The candle-power notion or concept is more or less fictitious, superfluous, though convenient for many purposes. For other purposes, the candle-power notion cannot enter in; we must come to the idea of luminous flux and base our computation of illumination on the idea of a luminous flux, as is quite evident when we consider any space illuminated by the so-called indirect method, where the ceiling is brightly illuminated, and, serving as a secondary source of light, illuminates other parts of the room. Evidently, there is no candle-power there, it is all a case of luminous flux from the ceiling falling on other surfaces of the room and illuminating them.

I think we are to be congratulated that this first, and certainly we hope the true, solution for the absolute definition of a standard of light, emanates from this country, and is presented for the first time to this Institute.

C. A. Perkins: It is not necessary for me to add my congratulations to Dr. Steinmetz for his valuable paper, but I wish to emphasize the fact that it is a step toward the solution of a problem which is impossible from its nature.

As Dr. Steinmetz has just explained, illumination is a physiological phenomenon and cannot be measured. It is impossible to say that a red light is as bright as a blue light. It is impossible to say that a Welsbach burner is so many times as bright as a Hefner lamp. The ratio depends on the eye of the observer, and also is a matter of personal estimate or judgment, and is not capable of measurement.

Yet the proposed standard simplifies the problem of comparing lights of different colors very materially, by reducing all the colors to three.

The next step will be to fix upon numbers which may represent the brightness of each of these primary sources (in candle-power per watt) based upon the average judgment of a large number of observers. The number thus determined will be more or less arbitrary but will represent in a fairly satisfactory way the average judgment and the normal eye. When the relative brightness of the primary sources has been fixed upon, the various secondary standards—Hefner, pentane or incandescent lamps—may be expressed definitely in terms of the primary standards, and the comparison of colored sources will be definite, though it cannot be absolute.

John B. Taylor: Dr. Steinmetz has several times told me that he had no proper musical training or appreciation, but in this paper he gives us a rainbow set to music, and leads me to hope that he has taken up a new subject, old as an art, but still having many unsolved physical and mathematical problems.

I wish to point out a few discrepancies as they appeal to me. In the first place, if we are going to replot the spectrum on a rational basis, why do we use wave-length at all? The essence of light, as well as of sound, is a matter of frequency, and not wave-length. Sodium light has a certain rate of vibration, while its wave-length is only incidental to the transmitting medium, having one value in air and other values in glass, water, etc. The same is true of sound. Pitch depends on frequency, while the wave-length of a sound of given pitch has different values in air, hydrogen, water, and wood. So it seems we should rightly lay out the spectrum on the basis of frequency instead of wave-length, frequency being really the essence of light and color.

I agree with Mr. Hering, that the English and American names of the musical tones would be more appropriate for this Institute. The German " cis's " and " fis's " are not so familiar to most of us as c-sharp and f-sharp which in addition to the misprints and backward arrangement have obscured the optical and acoustical comparison. The use of frequencies, rather than wave-lengths, will naturally bring red on the familiar left end of the spectrum and the musical scale will read from left to right.

I do not see the arguments for a logarithmic scale in representing the spectrum. The musical system, both melodic and harmonic, is based entirely on the *ratios* of frequencies, and music as written is essentially a curve or curves with time as abscissas and logarithms of frequencies as ordinates. I have never yet been able to find that there is anything in the optical scale corresponding to this matter of ratios in the acoustical scale. It is true that certain combinations of colors will be harmonious while other combinations will not be pleasing. For example, it is generally agreed that pink and red do not go well together. Is it possible to take two different colors and say that these are not harmonious, on account of the ratio of their frequency? There is a definite period in music. In a well-recognized sense, after the interval of an octave, we go over the same ground again.

I hope Dr. Steinmetz can show more clearly some periodic property of the spectrum or something depending on ratios of frequencies to justify the logarithmic plot.

Carl Hering: Dr. Sharp says there is some confusion of terms in my remarks. I am confident that Dr. Steinmetz will agree with me that his proposed unit is *not* a unit of illumination, as Dr. Sharp says, but a *unit of flux*, which is equivalent to illumination multiplied by an area, or candle-power multiplied by a solid angle—either one gives the same result. I am quite familiar with the various units and measures of light and the relations between them, as I gave some attention to this question of equivalency between watts and light some years ago and I am sure there is no confusion in my mind.

E. B. Rosa: I am interested in this proposition of Dr. Steinmetz, and should sincerely like to see it realized. It would be important to make a serious attempt to get a primary photometric standard in this way, which should be sufficiently satisfactory to be considered to solve the problem. It seems probable that it might be somewhat difficult to make the energy measurements with the required accuracy, and perhaps this will prove to be an insurmountable difficulty; and yet I have no doubt that if the attempt were made seriously, sufficient information and experience would result from the work to pay for the effort, even if it did not result entirely satisfactorily. It often happens that when a serious effort on a difficult problem is made and continued, a great many new things appear in the work that are of considerable value, by-products, so to speak, of the investigation. I think this field might be a very valuable and promising one to investigate thoroughly, with the hope, of course, that the problem of finding a primary photometric standard would be solved. At any rate, I think it would be proper to consider it very carefully.

I appreciate also the words of confidence in the Bureau of Standards that have been expressed. This investigation is clearly in the field of work of the Bureau of Standards, and the Director of the Bureau would be very glad, I have no doubt, to take up the work without any request from this Institute, as soon as practicable. Nevertheless a request made by the Institute would be very proper, and I would be glad to see that request made formally, because, as you will easily understand, the Bureau has so many fundamental problems on hand, more than it can at present undertake, that it needs support in its work; it needs the expression of confidence of this Institute, and the moral support of the engineering fraternity at large in its work. Such support will enable it to get the assistance and to develop the force that it needs in order to take up such problems, and therefore it can do more of that kind of fundamental work if interest is expressed in such a concrete way as is here proposed. I can easily see that such an investigation might last over a considerable period of time. We now have some problems on hand that have already extended over considerable periods of time, but in most cases they have been very profitable investigations to pursue; and entirely apart from the primary objects of the investigation, the results have been of considerable importance.

I wish again to express my interest in the suggestion of Dr. Steinmetz, and certainly consider it of value.

Carl Hering: I make the motion that the Board of Directors of this Institute be requested to refer to the Bureau of Standards the question of the establishment of a standard of light as proposed in this paper of Dr. Steinmetz. (The motion was unanimously carried.)

H. S. Carhart: I have only a few words to add to what has already been said. I suppose the reason why Dr. Steinmetz has chosen three distinct wave-lengths to enter into this combination for luminous intensity or luminous flux is the fact that there are three distinct primary color sensations. It would be desirable, first, to be assured that we get an average determination of the wave-lengths of these three primary colors, as applied to the eyes of different individuals, because there is individuality in this matter. Secondly, we should measure the relative energy in the three wave-lengths to produce any definite color, such as yellowish white. This task would be one of considerable difficulty. In that way we should be able to get the average energy of the primary colors required to reproduce a light of any given tint and intensity. It can readily be seen that such processes as these would necessarily require a good deal of time in order to realize them.

I think one of the speakers has been confused a little, if I may call attention to the fact—the mixture of three colored lights is a totally different thing from the mixture of pigments. The mixture of pigments is a process of absorption, and the mixture of lights is a matter of superposition and addition. If we have red glass, which cuts off the violet end of the spectrum, and blue glass, which cuts off the red end of the spectrum, and if we put one in front of the other, the only light that comes through is a little of the red. This is like the mixture of pigments. We should be very careful not to confuse mixture of pigments with mixture of colors. What we have in the paper is three colored lights, coming from three sources of definite wave-length. I am greatly interested in the proposition, and think it is really hopeful enough to suggest to the Bureau of Standards, as has already been done, for investigation.

Chas. P. Steinmetz: Three colors I selected as primary colors, since three primary colors are sufficient by their combination to produce all other colors, representing these by the ratio of the energies of the three primary colors. As seen, this is essentially the representation of the points of the color plane by a system of symmetrical coördinates. Combinations of two colors are not sufficient to produce all other colors, but at least three are needed. In regard to the selection of the three primary colors, I tried to get three colors forming as nearly as possible an equilateral triangle in the polar diagram, or in the color plane, as shown, so as to get the maximum accuracy in their combination. There was a second consideration. The three points of the equilateral triangle I tried to select so as to have a maximum distance from the ends of the spectrum, since at the ends of the spectrum the physiological equivalent of power is low and vanishing, and therefore if one of the lines were chosen close to the end, as for instance dark red, it would mean there would always be a large percentage, in power, of red rays, even to produce a color which appeared to the eye deficient in red. For greatest accuracy, it is however desirable to have the three numerical values of power of primary colors as nearly of the same magnitude as possible. The two outside colors, blue and red, are therefore chosen about equidistant from the ends of the spectrum, as two corners of the equilateral triangle, which brings the third corner into the middle of the spectrum, in the green. You can choose any other set of spectrum colors, but I believe the best way would be to choose the three points of an approximately equilateral triangle, with the two outside corners as far away from the ends of the spectrum as possible, as was done by me.

As regards the scale adopted, I must apologize, for my musical education was so badly neglected that I still used the Italian scale, instead of the flats and sharps of the English notation. I believe, however, it will be equally intelligible.

As regards the wave-length, what I give is not really the logarithm of the wave-length, but the logarithm of the frequency. The wave-length of light is not constant, but a function of the medium. However, the logarithm of the wave-length in any medium is the same, and is also the logarithm of the frequency, except with reversed sign and shifted decimal point. It therefore is immaterial, in the logarithmic scale, whether wave-length or frequency is used; either gives the same curve or figure, except turned over, and it obviously is immaterial whether the red end of the spectrum is on the right or on the left side.

In regard to the bearing of the acoustic scale, you will see if you look at the polar diagram, that it is material, and that the wave-length is not the right measure. In the acoustic or polar diagram, two diametrically opposite points are of complementary color, that is, combined give white light, or approximately white light (after all " white " is a rather indefinite expression). This is not the case in the representation by wave-length, nor in the representation by frequency; but in either case you find that one-half of the visible spectrum represents much less variation of the physiological effect, that is, change of color, than the other half.

About color representation: If we represent colors by a combination of the three primary radiations, we still have different values for the same color, representing different color densities. For instance, a certain yellow light may be represented by: red, 50; green, 50; blue, 0. The same yellow light, but of a lighter shade, may be represented by: red, 45; green, 45; blue, 10. Still a lighter shade by: red, 40; green, 40; blue, 20; until ultimately you reach white light.

I believe that even the densest yellow light, produced from the primary colors: red, 50; green, 50; blue, 0, is yet not the spectrum yellow; that is, not as pure yellow as the spectrum yellow, and that the spectrum yellow would be represented by something like: red, 55; green, 55; blue, −10. This ratio: $55 \div 55 \div -10$ represents a point of the plane outside of the equilateral triangle formed by the primary-color points, and such probably is the case with the spectrum yellow and with all the spectrum colors except the three colors selected as primaries.

Physically, this means that if we desire to compare the spectrum yellow with our three-color combination, no combination of red, green and blue can be found to equal the spectrum yellow, but that a combination of red and green can be found to equal a combination of the spectrum yellow and blue, and in this case the blue becomes subtractive. It is the same as balancing a weight by putting too much weight on the other scale, and then putting some weights on the first scale, *i.e.*, balancing by taking some weights back. We may do the same in color representation. Theoretically, I believe all pure spectrum colors, except the three selected as primary, would be represented by combinations of the three primary colors with one of the primary radiations as negative.

As regards the mechanical equivalent of light, I do not agree with the value mentioned by Mr. Hering, 0.188 watts per candle-power, for the reason that efficiencies of arcs have been measured which give lower watts per mean spherical candle-power than that. In some powerful titanium arcs values considerably lower have been found, and in those cases the efficiency was still far below 100 per cent. Estimating the loss of power by invisible ultra-red and ultra-violet radiation, by heat conduction, heat convection, air currents, etc., the efficiency was undoubtedly below 50 per cent., probably nearer 10 per cent. I believe the approximate equivalent of white light is probably something more nearly fifty candle-power per watt—that is, 0.02 watts per spherical candle-power. I make no claim to this value, but it is merely an estimate based on my experience—it may be more or less, but I would expect the equivalent of white light at approximately 50 candle-power per watt, or thereabouts. For other colors of light there would be different values. Probably in the case of the green light, the candle-power per watt would be much greater, in red light or blue light much less. It is a function of the color.

DISCUSSION ON "MEASUREMENTS OF LIGHTNING, ALUMINUM LIGHTNING-ARRESTERS, EARTH RESISTANCES, CEMENT RESISTANCES, AND KINDRED TESTS", "TESTS WITH ARCING GROUNDS AND CONNECTIONS", "CRITICAL STUDY OF LIGHTNING RECORDS ON TAYLOR'S FALLS TRANSMISSION LINE." ATLANTIC CITY, N. J., JUNE 30, 1908

J. F. Vaughan (by letter): It is gratifying to have a careful, independent analysis of the Taylor's Falls lightning records such as Mr. Thomas has given in his paper, and interesting to see wherein his conclusions differ from those of the original papers on this subject.

The main idea suggested by Mr. Thomas' paper, that the more pronounced disturbances at least have been due to some form of direct discharge between clouds and line, is fundamental, and requires radical modification of present conceptions of the nature of the direct stroke. It suggests that such a stroke may be:

(1) Of length varying from a few feet upward.

(2) Of quantity and intensity varying from a relatively small disturbance to a destructive bolt.

(3)* Of such a nature as to distribute itself with considerable uniformity over sections of line and overhead ground wires.

(4) Of frequent occurrence, amounting to hundreds of strokes during the season.

The main objection to the " Release of bound charge " theory is that the capacity of the line is not sufficient to account for the volume of discharge indicated by the tell-tale records. However, the potentials and rates of discharge may be sufficiently high to compensate for the relatively small capacity. There is little evidence of any great amount of energy in the discharges even in the shattering of insulators, providing a high enough rate of discharge is assumed.

There is, however, ample evidence of extremely high velocity of disturbances in the rapid damping out of potential in the line, the mechanical nature of the insulator fractures, the activity of line choke coils and the splitting apart of the laminations of the tell-tale papers.

In the discussion of overhead ground wires, Forms A and B, the records of storms of July 4 and August 18 are not considered as showing definite protective power. By reference to the original curves (Fig. 12 of the writer's paper) the record of the storm of July 4 shows by the activity of overhead ground wires A and B that the latter were well within the active area of the storm. If the curves representing line-insulator stress and overhead ground-wire discharge are added together this fact will be evident. The curves for the ground-wire sections on each side of the storm center show that as the center is approached the activity of the sections increases rapidly, with no corresponding increase of stress in the line insulators until the unprotected section of line between the shielded sections is approached within a few hundred feet; that is, the shielding effect of the wires appears to be pronounced even to within a few hundred feet of their ends. The storm of August 18, which was reported as the most severe for years, was active over ground wire B. Although the discharge from the ground wire was considerably larger than in any of the other storms, the average disturbance in the line shielded by this construction is shown by the curves to be low compared with those of unprotected sections in other storms. Over the central portion of this section of the line there is only one heavy spill-over, and as that is within less than 1000 feet from the end of the ground wire it may have come in from the adjacent unprotected section.

---

* See original paper by J. F. Vaughan. Fig. 12. curves of July 4.

Mr. Thomas calls attention to the probability that the side transmission wire towards the direction from which the wind blows is probably subject to more disturbance than the other wires. This exposure is shown in the general graphic chart by greater activity in the wire toward the approaching storm, excepting where the storm is overhead and near enough to cause spill-overs and physical damage, in which case the top wire seems to be the one most subject to trouble.

In interpreting the curves the following should be borne in mind:

(1) That the lower ranges of the scales of ordinates adopted for plotting the curves are exaggerated in order to show up the smaller values more plainly.

(2) That the discharge paths of the shielding-device grounds are freer than those of the line, and the discharges being consequently less disruptive are probably quantitatively greater than the line discharges for given sizes of puncture.

(3) That the sections of shielding wire are not long enough to insure the damping out of charges coming in from adjacent unprotected sections within the length of each shielded section.

In connection with the direct-stroke theory it is interesting to note that no clouds have been observed sufficiently low and close to the line to account for short direct strokes. Nor have any spill-overs been actually seen. Close watch is being kept on the line this summer to get information on the appearance of clouds and line during spill-overs, and the nature of insulator breaks is being further studied.

Charles P. Steinmetz: While some years ago the problem of electrical-power transmission and distribution, in its stationary condition, was already very well developed in most of its features, there always remained this class of phenomena, of which lightning is characteristic, which we may call transient phenomena; that is, phenomena which last only a short time, frequently an extremely short time, which but are of such a character that the damage they may do makes up entirely for their short duration.

We are approaching a clearer understanding of these phenomena and also a control of them, so that it looks not improbable that in a very short time lightning and all these disturbances in transmission lines and transformers will have lost their danger to us, that we will be as familiar with them as with the design of an alternator or of a motor, and that we shall be able to predetermine, control and eliminate them.

I am particularly glad, myself, to be able to see how the consensus of opinion of those engineers who are studying the subject most deeply is coming around to what I have maintained so many years, that the most effective protection of the transmission line is through overhead grounded wires. Some years ago, very few people agreed with that statement, now we find that most of them agree with it, and even these few doubting Thomases will, I hope, be convinced.

I believe to protect an electric system efficiently and effectively it is necessary to protect the line and protect the stations. We cannot expect to escape damage, no matter how complete the protection we install in the station, if we leave the transmission line unprotected. Neither is the protection of the line alone sufficient; but what I believe we can already, at this time, ascertain with fair certainty is that if the transmission line is well protected by overhead ground wires, whatever disturbances we get will not be so severe that we can not take care of them safely by protective devices in the station.

I do not quite agree with Mr. Thomas in explaining the disturbance in the Taylor's Falls transmission by direct strokes, or rather, to explain it more fully, I do not see an essential difference between a direct stroke, as described there, or the phenomenon of the bound charge of lightning.

Let us see what happens in a direct stroke. If the potential difference between the line and cloud rises so high that somewhere in the field the potential gradient exceeds the breakdown strength of air, a breakdown occurs, as a discharge from line to cloud, or into space, thus equalizing the potential. In the other case, if by a discharge in the clouds the potential difference between the clouds and ground is suddenly changed, the bound charge of the line is set free, and that means that suddenly upon the line a very high electrostatic potential is impressed which discharges from the line into space, if the voltage is beyond the disruptive strength of the surrounding space. In either case—whether this potential difference is created by a discharge into the cloud, setting free the bound charge, or whether it is created by potential difference between the cloud and ground—if the voltage is high enough, the discharge passes from the line into space, toward the cloud. I thus do not see how we can distinguish the phenomena of the bound charge from the phenomena of the direct stroke, but believe these two phenomena are practically the same.

There is only one point I want to mention, and that is to express my regret that in the tests and investigations valuable records have been lost by the combustion of tell-tale papers. These tell-tale papers can be protected by fireproofing, and I bring that to your attention, because it can easily be done (and it is very desirable to do it) by treating these papers with a solution of sodium tungstate (also called sodium wolframate). They become fireproof by such a treatment, and there is no longer danger of losing them or setting fire to them. A quarter of a pound of the sodium tungstate bought at any wholesale drug house, is dissolved in a pint of hot water, and the tell-tale papers immersed in that solution, and then dried. There is no apparent change, except that the paper is slightly rougher. You can write on it the same as before, the lightning discharge makes the same markings, the same punctures appear in the tell-tale paper, but it cannot be set on fire, the flame cannot consume it, and therefore you cannot lose any of the papers by fire. I believe it is very desirable to carry out this precaution. I do not know that there is anything else to add, and I thank you very much for the opportunity of expressing my opinion on these papers which have been presented.

P. M. Lincoln: I agree with Mr. Steinmetz that the most important question raised by the lightning-arrester papers is that of the ground wire, and I will take issue with Mr. Thomas in his interpretation of Mr. Vaughan's results which were presented to the Institute at the last meeting. In my own interpretation of Mr. Vaughan's results, I found to my own satisfaction that there was a very marked protection given to the line at Taylor's Falls by the presence of the overhead ground wire.

Possibly I have not given this matter quite such close attention as Mr. Thomas, but I would like to have him detail, if he will, the reasons why and how he can draw conclusions to the contrary.

I would like to ask Mr. Creighton, too, whether, or not the record obtained by him in Figs. 3, 4, and 5 were obtained with current on the line, or whether the line was dead at that time. I presume there was no power current on the line at the time the records were taken, judging by their shape. I would also like to ask Professor Creighton for his opinion as to the efficacy of the overhead ground wire.

A. E. Kennelly: Overhead wire protection is a matter of very great importance on account of the radical nature of the construction which it involves. This matter is one concerning which experience of some kind has been gained for more than fifty years; that is to say, ever since overhead wires have been put up for telegraph purposes there has been the same trouble with lightning, differing only from the trouble that transmission engineers have had, in the fact that the poles were ordinarily not so high as at present, that the insulators were very much weaker electrically, and that instead of having a high potential dynamo at the end of the circuit, there was no appreciable power on the circuit. Nevertheless, the damage done by lightning was recognized at a very early date. Apparatus was burned out, insulators were destroyed, poles were smashed or damaged.

It was found that the lower wires largely escaped. I think that is the consensus of telegraph-engineering opinion all over the world. The upper wires bear the brunt of the damage. Poles were found to be saved in very large measure by putting grounded wires on the pole themselves, putting a lightning protector on each pole. The upper wires were not grounded every half mile, as is customary with protecting wires; but nevertheless the protection of overlying wires grounded at distant stations was found to be material, although incomplete.

It is my expectation we shall never have any system of absolute, complete protection against lightning, even with the best devices that we can install in the station, or the most perfect system of overhead grounded wires that we can devise. We can hope with care to minimize the damage due to lightning, but we shall always have some trouble left. Any one who looks for a panacea against lightning is entertaining a very courageous expectation, which is likely to meet with some discouragement.

I think that we ought not to attempt to form too definite a conclusion as to the source of lightning disturbances upon the wire. Mr. Thomas intimates that the disturbances are mainly due to little direct strokes, but others think, from the same records, or with the same data before them, that the disturbances are due to the release of bound charges; while still others think they are due to inductive disturbances. There are so many possible causes for disturbances that we should hold our minds open and not consider that everything is due to one and the same source of injury. For example, in the case of an overhead wire, we all know that there is a movement of electrified air over the wires conveying electrical charge to them continuously. Secondly, we have the release of bound charges, and thirdly direct strokes. Fourthly we have a source not generally recognized, namely, electromagnetic waves. If over a distance of several miles there can be produced in a wireless telegraph antenna a received e.m.f. of fifty or one hundred volts, from a small alternator at the generating station, surely a lightning discharge with its enormous generating power is able to produce electromagnetic—wave disturbances in long wires of very much greater magnitude.

It seems, therefore, that we should not try to formulate a rule and declare that all disturbances due to lightning in overhead transmission wires have one and the same origin. We must expect, with a number of disturbances, that a number of different kinds of apparatus may be necessary to be installed, some to protect against one kind of disturbance and others to protect against other kinds of disturbance.

John B. Taylor: Professor Creighton has shown his ingenuity in devising special pieces of apparatus to determine what is actually going on in a transmission line. We wish to know what we have to guard against, and I think that papers of this sort are more to be desired than many we have had in the past. The conditions of operation are so variable that some conclusions drawn as to the better of two types of arresters are not justified; but when we know what we have to deal with, and to a certain extent can duplicate the conditions in the laboratory, then we can begin to produce apparatus which will meet the requirements.

I have not had a chance to give this paper as critical reading as I would like, but there is much confusion in my mind over the use of the term "lightning." I do not know why the word lightning should be applied in a new sense. The word has been in use for many years, and almost everybody in the profession, and out of it, has a pretty definite idea of what the term signifies. Professor Creighton, apparently, wants to call anything abnormal on a transmission line "lightning". When he speaks of the natural frequency of lightning, does he mean the natural frequency of the lightning stroke from the clouds, or the natural frequency of the discharge of the line, with which he is experimenting, to ground? The records show mainly frequencies of three thousand cycles, or in that neighborhood, and as I read the tests, this frequency is merely the one at which the particular line discharges to ground, and gives no indication of the frequency of the lightning discharge itself. The variation between 3,000 or 4,000 and 15,000 may be due to the distances out on the line at which the lightning discharge proper occurred. I trust he can give us a little defense of this use of the terms, because to my mind it has made a good deal of misunderstanding in reading the paper.

Reference is made to a further analysis showing in addition to 3,000 cycles or thereabouts, superposed higher oscillations of a million cycles. I believe he used the term lightning as applied to these million cycles. How can a lightning stroke a mile or more in length be expected to oscillate with a frequency of a million cycles? A stroke a mile long, with a period of oscillation of one million cycles, would mean a velocity of at least one million miles per second, whereas the known velocity of light and electrical impulses in the ether is only approximately 190,000 miles per second. Does the apparatus demonstrate this high frequency in the lightning stroke or is it the period of parts of the test line and apparatus—a secondary effect of the lightning?

The data given on actual resistances of ground connections is valuable. The putting in of these ground connections goes largely as a matter of chance, and more perhaps as a matter of faith. We put up an expensive equipment of lightning arresters– and then run some kind of a wire into the earth, and seldom make tests to determine whether the latter is effective or not.

From one test, a value of 30 to 40 ohms is given as the actual resistance of the ground itself between two points several miles apart. I think there must be some mistake in this, as judging from a test made in dry rocky soil, the resistance of the earth, apart from that at and near the contact plates, is not likely to be anywhere near so high. Was this measurement made with alternating or direct current?

Mr. Berg gives us figures from tests of practical value, because the arcing ground unfortunately occurs at times on transmission systems. Mr. Berg does not offer any explanations as to the cause of this excess potential, and possibly in discussion he may give us his idea of it.

What appears to be the simplest explanation of this excess potential, as evidenced by the needle gaps, is a compensator or auto-transformer action in the transformer itself. The windings of the transformer have electrostatic capacity to ground, which capacity is not evenly distributed along the winding, but is greater in some parts than in others, giving an arrangement equivalent to condensers connected between points of the winding and ground. Considering one of these condensers near the terminal where the arcing ground is to take place, this condenser will become charged to a high potential, and as soon as the gap to ground breaks down, the charge will pass through a small portion of the transformer winding, stepping up the voltage at the other terminal of the transformer. Where two transformers are interconnected in an open-delta arrangement, the normal potential of one transformer is added to this excess potential derived through compensator action in the other transformer. This might explain why one line terminal in the open-delta arrangement shows higher voltage to ground, by needle gap, than the other line terminal.

In practice, of course, the action is not as simple as this, on account of the complex nature of the distributed capacity, reactance of winding, losses in iron core, etc., but this explanation of the phenomenon seems to be a simple, rational one.

One word more on Mr. Thomas's paper. I want to take issue with him on his choice of terms. I cannot understand why the term "static" is used here to represent anything but a static condition. In the old days we had "static" electricity and "dynamic" or "galvanic" or "voltaic" electricity, and the study of static electricity had to deal with the distribution of charges on bodies of different shapes, the forces of the attraction and repulsion between bodies and when they were charged, and similar matters. The term "static" applies to a condition of rest. Now, we seem to use the term to call to mind anything but a condition of rest. The term has crept into this use in the last few years and I hope we can find some other word which will more truly represent the condition of affairs, and not upset a term which already has a well-recognized use in the older books.

R. H. Marriott: In the territory in which Mr. Creighton was making his tests there were several wireless-telegraph stations from 1905 to 1907. At these stations we had a great deal of trouble with what is called "static." There were four stations: one at Pueblo, one at Altman, one at Colorado Springs, and one at Denver. At the Denver station were two masts 200 ft. high and 300 ft. apart, with a station house half-way between. One aerial consisted of a flat-top loop in the same plane with the masts, and stretched across the top of the masts, and with the ends in the station house. Another aerial consisted of forty wires suspended from a cable, and in planes at right angles to the plane of the masts. The highest point reached by the forty wires was about four feet, directly below the flat portion of the loop. The relation of the flat-top loop to the forty wires was in some respects similar to the relation of the grounded overhead wire to a transmission line.

On a test made between points to ground while a thunder shower was approaching, the maximum discharge from the forty wires was approximately 2 inches high, and the maximum discharge from the flat-top loop was approximately 2½ inches. We accounted for the greater discharge from the loop as due to the fact that it was higher in the air than the forty wires.

At all the Rocky Mountain stations the wire that extended in the air the highest gathered the most static, as indicated by the wireless receiver, even though the natural frequency of that wire was greater or less than that of the lower wires.

There were about three months of the year 1906, June, July, and August, when we had bad static practically all the time, except between 3 a.m. and 6 a.m. The natural frequency, *i.e.*, the number of alternations in the discharge itself, was apparently at times about 1,000,000 cycles—so estimated because the tuner was set frequently at 300 meters, and the static impulses were received better on that tuning than on others. The tuner consisted of variable inductances and a fixed condenser. I should say, from my experience with these static discharges, that they were sometimes as low in frequency as 50,000 cycles, and sometimes as high as 3,000,000 cycles per second. The discharge frequency, that is, the number of sparks at Pueblo, on one test from a seven-wire, 200-ft. aerial across a 3½-in. spark gap to ground was one spark per forty seconds, whereas across a ⅛-in. gap a discharge took place about every one-half second.

We accounted in different ways for the static which troubled us. One explanation was that a discharge took place between a cloud and the earth, or between two clouds, setting up electromagnetic waves which traveled out like the electromagnetic waves from our transmitter, and thus set up oscillations in our receiver antenna. Another cause that we attributed the static to was that the air about our aerial had a potential difference to earth, and discharged to earth through the aerial. Another cause was friction of winds on the wires. In our telephone receiver, when attached to the wireless detector, the static makes a buzzing noise, weak static making a faint buzzing noise, and strong static making a loud buzzing noise. The strength of this buzzing during a wind storm increased with the velocity of the wind. This may mean, however, that when more air is passing more charges are carried to the wire.

I have never known of a wireless station being struck by lightning. In one case a report came in of damage to a station due to lightning, but on investigation it was found that the operator, not realizing the conditions, had moved an antenna from its original position, and had placed it above and across a 1300-volt line. The antenna guy ropes stretched, and grounded the line through our receiving instruments, which acted as a fuse. This occurred at Altman, where lightning is so common and severe in the summer that a description of its activities is almost unbelievable. The aerial here was 160 ft. in height. On one occasion when I was present lightning burned out a transformer situated about 100 yds. from the wireless station. These burnouts were said to be quite frequent. In Pueblo we had a 200-ft. tower mast at Minnequa Park, in a district in which lightning is said to strike very frequently. This mast, with 16 steel guys, broken by strain insulators, had just been completed, and a steel cable was pulled up about 100 ft. with its lower end lying on the ground. During the night lightning struck a one-story house about six squares away, but there was no evidence that it had struck the mast or any of the cables. It appears to me that the most probable explanation as to why these wireless stations were not struck is that the antennæ served as a path through which the charges above and around the antennæ gradually leaked to earth; thus preventing the accumulation of a sufficient quantity of electricity, at any one time, to cause damage upon discharging. This explanation is based on the fact that the severest static occurs shortly before a thunder storm reaches a station.

D. B. Rushmore: Our knowledge of lightning phenomena is constantly increasing, and the operation of lightning arresters is each year becoming better understood. For much of this we have to thank the oscillograph.

Some caution is necessary in interpreting the results of indications caused by the puncturing of a piece of paper. It is possible for discharges to take place over series resistances which puncture paper and which have the optical effect of a considerable discharge, whereas in reality the conditions may be such that but little relief is afforded to a rise of voltage.

A great deal of engineering must be done on more or less inexact knowledge. This is true of the use of a ground wire, where it is difficult to get exact comparisons of operation under the same conditions with and without that protection.

Complete protection against lightning is being more or less closely approximated at present. From the experience which the speaker has been able to gather, it would seem that a transmission line can be practically protected against atmospheric disturbances by appropriate tower design, by the use of one or more ground wires, by the use of lightning rods and by the use of a much higher factor of safety in line insulation than has been customary. With modern protective apparatus, intelligently installed and kept in efficient working condition, it should be impossible to obtain a rise of voltage in that vicinity.

It would seem to be a fair statement to say that we are now at a point where, with the best apparatus installed in the best possible manner, and with the most careful design of transmission lines, practically complete protection against lightning can be had.

J. W. Fraser: I want to say a few words commending the work that has been done on this subject, and that has made possible the papers which we have heard this morning. The scope and thoroughness of this work is highly deserving of mention, and I am glad to see such a large attendance, and to find that so many of the members have taken such a deep interest in this work; for it is only by such intelligent and painstaking investigations that manufacturers can obtain sufficiently reliable data to give us an arrester which will be of real service under all conditions.

In the past it has been the practice of the Southern Power Company to install alternately a multigap or low-equivalent arrester, at all their sub-stations, in addition to the grounded wire over both steel and wood lines; and this company installed last autumn and this spring fourteen aluminum-cell arresters, half of one make and half of another, at various points on the lines. Several severe storms have passed over different parts of the lines since these arresters were put in service, and they seem to be doing good work. On grounds these arresters have operated continuously for several minutes, apparently with very small variation in the voltage.

Although there are 315 miles of 44,000-volt line with 98 transformers, and 50 miles of 11,000-volt line with 48 transformers in service on the Southern Power Company's line, most of which were installed last summer, only one transformer has been lost, out of the entire number in operation, from causes traceable directly to lightning. It is to the credit of the manufacturers that this is the case. True it is that a few terminals have been burnt off and a few bushings broken, but such troubles are not comparable with burnt-out transformers, and show the necessity for a better path to ground than the old arrester.

It has been the intention of the Southern Power Company to make a systematic study of lightning and freak voltages, but so far all that has been done is to keep an accurate log of all disturbance on lines since January 1, 1908. Out of the twenty-one lightning storms which have passed over the lines since that time, eighteen were severe and three were light. Out of eight storms there was no damage of any kind. In five storms, a total of about a dozen insulators had either one or two petticoats broken off; in two storms two meters were damaged; in two storms one leg of three 44,000-volt oil switches were punctured; in one storm, one 2200-volt oil circuit-breaker blew up (no current on the transformer and the lightning struck a short secondary about 300 feet long); in one storm, transformer leads were burnt off two transformers inside the case; and in two storms the line was grounded through a punctured insulator and caused considerable damage.

The most difficult thing we have to contend with is a grounded conductor. The overhead grounded line and the old form of lightning arresters seem to take care of ordinary lightning storms comparatively well but as soon as a conductor gets grounded, due to any cause, there is sure to be a fire display over the entire system and damage is inevitable. We believe, however, from the experience we have had with the aluminum-cell arrester that this arrester will be of great service in trouble of this nature. Its ability to withstand continuous discharge for some time without varying the voltage materially gives it a place unheld so far by any other arrester A rather peculiar incident happened the night before I left to come to this meeting. I had just read the part of Mr. Creighton's paper that refers to the station grounds, where he cautions every one to couple all grounds, when our Superintendent of Construction came in and related an experience he had had that day bearing out Mr. Creighton's warning. The Superintendent had two heavy steel towers erected in concrete across the tail-race of the Great-Falls Power house and was guying to an old cedar stump the end of a messenger cable which he had strung between the towers to carry conductors across. He and five of his men who had hold of this wire received a very severe shock and heard the electrolytic arrester about 200 feet away discharge and hold for an instant or two. As soon as the arc broke the men were relieved. On investigation it was observed that the end of the pipe to which the arrester was grounded was only five or six feet away from the men's feet, and that the earth was comparatively dry around the pipe, which was only a few inches in the ground.

This pipe was not installed for a ground but for part of an old water main used in construction. It is quite evident that the current was seeking a better ground through the foundations of the steel towers, the concrete of which was still moist.

Mr. Thomas speaks about the bits of paper being punctured in various places. An insulator on our line was punctured in three separate places and shows the slag formed evenly around each hole.

W. L. Waters: I was much interested in the conclusions which Mr. Berg draws from his experiments. He finds that whenever we have an open-air arc on a circuit, we get extremely high potential rises on the end coils of the transformers. According to his figures, we would get a potential rise equal to about 15 or 20 times normal voltage on the first 200 turns. This will probably mean that we get a potential rise of 100 to 200 times normal on the end turn of the winding, and it should be remembered that this potential rise is not a sudden strain merely but that it continues as long as the open-air arc is on the circuit. I think that only a transformer designer can realize how serious such a potential rise would be. On large 60-cycle transformers we have up to 200 volts per turn normal potential, so if we get this sudden rise, described by Mr. Berg, it might mean 40,000 volts on the end turn of the transformer. It would not be commercially possible to insulate the transformer to stand such a high voltage between turns.

The only suggestion which Mr. Berg offers for protecting the transformer is to place a series of condensers across the various coils. There would be little difficulty in insulating the individual coils of the transformer for high voltage—the great difficulty would be in insulating the end turns of the individual coils. For these condensers to be effective, therefore, they should be connected between the various end turns of the transformer coils. I think it will be realized that the suggested remedy of putting condensers across the individual turns of the transformer would do little good, besides being unpractical. It is well known that the weakest parts of a transformer are the various voltage taps which are brought out, and I think it is easily seen that the additional danger due to numerous taps being brought out from the winding to the condensers would offset any advantage which might be gained from their use. The additional cost and complication of this series of condensers would also make the size and cost of the transformer prohibitive. I think that the only practical method of protecting the transformer against these high-potential strains is the insertion of choke coils between the transformer and line. These choke coils will most certainly afford some protection to the windings, and it is just a question of selecting choke coils with the required constants to give suitable protection.

I rather think, however, that Mr. Berg in his experiment has chosen conditions which are in some way different from practical operating conditions. We have been operating transformers for the past fifteen years on power circuits which are exposed frequently to open-air arcs and have been doing this without any extra insulation on the transformer windings and without choke coils. According to Mr. Berg's experiment, we ought to lose our transformers every time we had an open-air arc on the circuit, and we all know that this is not the case. I think, therefore, that Mr. Berg must have some special conditions present in his test which caused him to obtain unusual results, and that he should guard against drawing general conclusions from a limited series of special tests.

William McClellan: After some experience with lightning arresters at voltages varying from 11,000 to 60,000, I cannot help but think that the two methods of obtaining data as shown in the papers of this morning, while both valuable, fill very different places in the study of the subject.

So far as effectiveness is concerned, the speaker believes the method used by Mr. Creighton is of the very highest value, and it is with the greatest pleasure that he bears testimony to his enjoyment in reading the paper. It seems almost certain that the final solution of the problem will be reached by this method sooner than by any other.

It must be conceded that results obtained by a test-paper method can only be corroborative of the conclusions and predictions obtained from the experimental methods. As is well known in all laboratory work, results can only be obtained when conditions can be isolated, and most engineers will agree that in work of this kind isolation is well nigh impossible so far as commercial lines are concerned. The variables are so many, the causes of each are so subtle, that it is difficult to get any positive knowledge of what the conditions are at the time the phenomenon occurs.

It would be well for all to note that the real problem at present in lightning protection arises in connection with transmission lines. It may safely be said that we can protect at present any kind of station, and all the future can do is to make this protection simpler and less expensive. We are far, however, from a solution of lightning protection to transmission lines. In this connection the writer can only repeat his opinion, expressed before, that the ground wire will be found eventually to be the only real method which will give protection. But the ground wire, to be adequate, will have to be installed in a more elaborate manner than is now customary. There is no doubt that in time to come we shall build our transmission lines with as much care, and they will warrant as much expense, as a high-speed railroad right of way. I think we must recognize sooner or later that if the transmission line is to be protected adequately, so as to give practically continuous operation, we shall be compelled to put on it several times the expense that we do at present. The error we are making at present is in attempting to get line protection cheap.

Farley Osgood: I would ask Mr. Thomas if he can tell us from these tests something about the limits of the area of the disturbance. Not very long ago most operating engineers felt when a lightning storm came that they were likely to feel the effects of it everywhere in their system. A number of my good friends now tell me that half a mile is likely to be the limit of the area disturbed. Possibly in the test made on the Taylor's-Falls line this point was brought out. If I remember Mr. Vaughan's paper correctly, it indicated that one-half to three-quarters of a mile seemed to be about the limit of severe disturbances, but as an operating engineer, I feel safe in saying that we dare not have very great confidence in that statement.

I would also like to ask if any of our friends can tell us what benefits are derived from serving the phase wire near the insulator. This practice is not a general one, but some of my friends follow it and they record remarkable results in the loss of a great number of insulators without the parting of the phase wire. I therefore simply bring it up as a matter for discussion.

I wish to agree with Mr. Rushmore about forming final conclusions from the results of the tests and experiments which are now going on. His reference to Mr. Thomson's chain of lightning disturbances reminds me that a year or two ago, when the sun spots were observed, and it was supposed this condition would give us a good deal of trouble, our good friends who seemed to be in pretty close touch with the folks who send us lightning storms, alarmed all the operating engineers at the prospect of some terrible lightning storms that season. These conclusions were based on very careful study, but as a matter of fact I think we had less disturbance from lightning storms that year than in any previous year.

Dugald C. Jackson: I wish to call attention to the enterprise and foresight of the manufacturers who have supported the experiments Mr. Creighton carried on, and likewise of the owners of transmission lines who have supported the experiments presented by Messrs. Vaughan and Neall. We have been this morning viewing the papers from the standpoint of the results that have already been attained. Now, these results are large, but they are merely indicative of the path to be followed toward a solution of the lightning difficulties. I believe that Dr. Kennelly is too much influenced by his experience in the telegraph art, when he throws out the inference that lightning protection for transmission lines will not be reasonably perfect in the future. We spend so much money for the insulation of transmission lines as compared with the insulation of telegraph lines, and the value of the apparatus to be protected is so great as compared with that in the telegraph lines, that we can afford to spend enough money to protect transmission lines and protect them thoroughly.

It used to be said that successful paralleling of alternators was impossible. Now it is one of the commonplace matters of engineering practice, this paralleling of alternators. Of course, now and then an accident occurs to paralleled alternators, but that does not alter the fact that paralleling of alternators is successful. Likewise, we seem to be in a fair way to soon see the "impossible" accomplished in the protection of transmission lines. The experiments that are now being carried on with transmission lines are doing more to bring us to a real knowledge of the characteristics of lightning strokes, and of the measures to use for protecting the lines from their injurious effects, than everything that went before. We should view the experiments that have been set forth in these papers from the standpoint of what they lead toward, and also from the standpoint of the great ingenuity and ability with which the work has been done,—not merely viewing what they show in completion. If such results and such methods of work as are laid down in Mr. Creighton's paper, or as are laid down in the paper that Messrs. Vaughan and Neall earlier presented, came from a laboratory of "pure science," these results and a statement of these methods would be heralded with acclaim. Coming from engineers, as they do, as part of the engineer's daily work, they are part of the craft of the engineer and we forget the tremendous labor and tremendous ability that has gone into the experiments, and our discussion is likely to tend toward criticism instead of encouragement. That does not seem to me to be in keeping with the pioneer character of the papers or fair to the art dealt with. A reasonable amount of acclaim given to the experimental results and beautiful methods used, will encourage and lead toward the more rapid extension of such work; a result which is earnestly to be desired. The Institute is fortunate in having these papers before it for discussion, and I desire to express my particular admiration of the manner in which the authors conceived and executed their experiments and presented their results.

Chas. P. Steinmetz: I caution you not to accept too broadly the statement that lightning disturbances extend only over a half-mile or less. This is really not the fact. I know from my own experience that occasionally when a lightning storm passes in the Hudson valley, the lights in my house, thirty or forty miles away, go out. The statement made in the paper is correct in so far as the disturbance produced by the lightning stroke, by its very abrupt discharge, extends only over a half-mile or less, possibly even over only a few poles; but internal surges produced by these lightning disturbances, as by a grounded phase resulting from the puncture of an insulator by lightning, extend over the entire system, and the latter disturbances are those which are most serious and thus most noticeable. Whereas the direct lightning stroke is only the starting point of the disturbance, the latter disturbances are really the phenomena against which we have to guard and hope to guard by the aluminum arrester.

With the statement made that transformers break down equally as often in the middle as at end turns, I cannot agree. It was the frequent breakdown of end turns which caused manufacturers to increase the insulation of the end turns again and again. The transformers, as they stand now, with the very heavy insulation of the end turns, may break down equally often at the end turns as in the middle, but this merely shows that the engineering design is correct, that we have increased the insulation towards the ends so much as to give the same margin of strength throughout the entire transformer. The equal frequency of breakdown throughout the entire transformer, with the much heavier insulation of the end turns, proves that the strains are far more severe toward the ends. If we left the end turn unprotected, you would find a very disastrous state of affairs.

Regarding the weird phenomena described by Mr. Berg in his paper: it is true we can make a picture of these, as Mr. Taylor shows, but what we desire Mr. Berg to give us some time is not a mere picture—how it happened—but we expect to get equations of it.

I have seen phenomena of the same character, which are quite curious. Some years ago we built a 500,000-volt transformer—this was quite some time ago, and we knew a great deal less of very high voltages at that time than now. With the transformer fully assembled, and with the terminals brought out from the oil, we were never able to run the transformer up to full voltage. It always broke down. If we took the terminals off, below the point where they come out of the oil, leaving the transformer connected with full voltage, we could run the voltage considerably beyond 500,000, without doing any damage. It was merely a case of a small terminal capacity, and by bringing the terminals out in the air, the brush discharge produced a high-frequency oscillation, which made the transformer break down internally, at a nominal effective voltage below that which it would stand as a steady stress.

E. E. F. Creighton: In reply to Mr. Lincoln's question, of whether there was dynamic current on when these records, Figs. 3, 4, and 5, were taken, I will say there was not. Of course, if there had been dynamic current there, the arc would have continued to play and the record would have been lost. The record shows nothing but the oscillations of the circuit.

In regard to the overhead grounded wires, I think that phase of the subject has been discussed pretty thoroughly. The overhead grounded wire cannot produce complete protection, but it will, as a rule, bring the protection within the range of the insulation of the line, and in that way reduce the probability of interruptions to a very small value. When a very heavy direct discharge strikes the overhead wire, there is still a possibility that the line will arc to ground due to "side-stroking." The farther away the ground wires are from the line wires, the less will be the danger from this source.

A number of years ago we made some laboratory experiments on the protection afforded by the overhead ground wire, and we found that the wire gave about fifty per cent. less sparking potential with the overhead grounded wire placed above it. The test was carried out by placing a large plate of sheet metal above the wires experimented upon, and regarding the plate as the cloud.

In regard to the storms themselves, there is no doubt that every storm varies in its characteristics from every other storm, to a certain extent. We might get an analogy by noting that in any dusty place, around a building or fence corner, every wind current or every wind storm that comes up has a different effect; but if you watch you will find that little currents or whirls of air will frequently form at certain places. You find the same thing with cloud effects. Out on the plains thunder clouds may appear anywhere. In the mountains the heated air in the canyons will cause thunder clouds to form repeatedly in the same location, and the mountains themselves give a direction to the winds. Although I think the direct observation of storms in general gives very little practical information in engineering, yet an attempt at classification explains some differences in their destructive effects. Not very long ago we observed a storm which was rather peculiar. It was made up of clouds in the form of an inverted cone. I was stationed at a point about two miles away from the apex of the cone, and I observed that the lightning strokes would start from all directions in the body of the cloud-cone and discharge at one particular point, the apex. The conditions are shown in the figure.

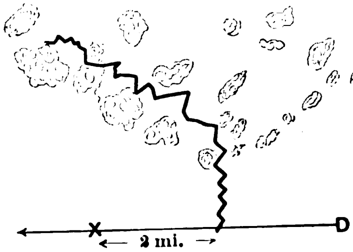


FIG 1

At the station where the speaker was there was not even rain until some time after the lightning display ceased. The electrical storm was severe but its effect on the transmission line was negligible. There were over fifty strokes at the apex of the clouds. If the apex of the clouds had been situated directly over the station or line the destructive effects would have been great, and the protective apparatus would have been called on for its maximum discharge rate.

The distance to the point on the earth struck by the discharge was located by the well-known method of counting seconds between the instants of seeing the flash and hearing the thunder and allowing five seconds to the mile. Since the apex of the cloud was only ten seconds distant and the thunder would roll for fifteen seconds after it started, some confusion would naturally be experienced unless the conditions were analyzed. There were at least three definite relations between the thunder and lightning which a fortunate situation relative to the storm aided in checking.

1. There was the flash to ground, followed about four seconds afterwards by mild rolling thunder, which increased in intensity up to ten seconds, and then ended in a loud crash. This thunder was due to a discharge which started in the clouds directly overhead at an elevation of nearly a mile and darted to the apex, gathering a greater quantity of electricity as it went. This increase in the quantity of electricity is not the only factor affecting the noise of the thunder. The wet atmosphere in the clouds relative to the dry atmosphere between cloud and earth was a good conductor. There would therefore be less tendency for the discharge in the cloud to collect in one streak. Between these two effects, the noise of the rolling thunder increased despite the fact that it came to me from a greater distance.

2. After an interval of ten seconds following the flash to earth the thunder started with a heavy crash, and then rolled during eight to fifteen seconds, gradually diminishing in intensity. This thunder was due to a stroke coming from the further side of the cone to the apex.

3. After the flash to earth there was an interval of ten seconds and then a crash of thunder with little or no rolling. This thunder was due to a stroke moving through the clouds to the apex at right angles to the point of observation. All the path of discharge being at nearly the same distance the sound from the different portions arrived at the same time, hence the lack of rolling.

Since the strokes occurred at intermediate angles also, these three effects were obtained only to a lesser degree.

The theory of the formation of thunder clouds leads to the conclusion that this conical form of storm cloud occurs frequently on the line.

Mr. Taylor questions the use of the word lightning to express all abnormal conditions of potential on the line. That name is due to Dr. Steinmetz—it was a very convenient term, and we adopted it. Subsequently, the use of the word "lightning" was discussed by several interested engineers, with the result that Dr. Steinmetz and the writer agreed to use the term lightning only in its time-honored sense—cloud discharges and their induced effects. Some general term is needed to cover the various abnormal surges which occur on a transmission line. Several words were discussed but none agreed upon.

Mr. Taylor brings up the question of lightning frequency. I think my statements will be clear if one accepts the general term lightning as any abnormal condition of tension on the line. A frequency of one million cycles per second was measured by a number of coils, described in the paper, and I am very glad to get the opinion of wireless-telegraph engineers that they also have noticed frequencies of that order, measured by a different method. Dr. Steinmetz has made calculations on the probable frequency of cloud discharges, and the value has come out of the order of a million cycles. A cloud discharge may have a frequency of only fifty thousand, or it may have no frequency at all—may be a non-oscillatory discharge. There is reason to believe that this latter condition may obtain under some circumstances. The lightning is gathering from perhaps miles around, or may be merely passing through a few acres of cloud, but in gathering it has to pass through a high resistance—pass from point to point in the clouds, in the form of brush discharge. Therefore, it seems reasonable to assume that certain lightning strokes can occur without any oscillations at all.

Mr. Taylor brings up the question of the resistance of the earth independent of the contacts. The usual contact resistance of an ordinary pipe earth, if well made, will be about fifteen ohms. It may be considered that the resistance is concentrated in the immediate neighborhood of the pipe. In the case referred to, the data are given for a condition out in the Rocky Mountains, where as the term indicates, everything is rocky—the mountains are composed of solid rocks. The rock is dry, hard, and of low conductivity. The conducting earth between the two points measured was in a very narrow canyon, consequently the resistance depended upon the distance. In another case the earth resistance was very much less, being only a few ohms. In a neighborhood where there is plenty of good loamy soil, and plenty of moisture, there is no doubt that the actual earth resistance, independent of the local and contact resistances, would be very small.

In regard to the questions brought up in connection with Mr. Berg's paper, I wish to corroborate the statement made by Mr. Berg, that the biggest problem we have to-day is not the protection against cloud lightning, but protection against the internal surges. Some of the worst conditions observed last summer in Colorado were due to these internal surges, combined with short circuits. This combination gives the worst condition that can exist on the line, outside of a direct stroke. A direct stroke affects only a small locality, whereas a grounded phase, combined with a short circuit, may affect the whole circuit, and usually does.

There is just one other point I wish to take up: the conditions of further study. Personally, I am indebted to a number of operating engineers who have assisted in this work, and the operating engineer has put up to him part of the problem which he must solve himself. So far as we are able to do so, we shall continue to study; but from the factory end we cannot hope to solve the entire problem, because the conditions on one line are not the same as on another. The problem relates to protection against accidentally grounded phases, the installation of the number of lightning arresters necessary to effect this protection, and the spark potential of the lightning arrester.

Now, in order to make a lightning arrester that is marketable, it is essential to keep the price down to a value which is comparable to the cost of the apparatus to be protected—say the transformer, the generator, or whatever it may be. This condition has necessitated the use of a gap in series with an aluminum arrester. The questions are: what gap-setting to use and how many of these aluminum arresters must be placed on a transmission system; that is, how many stations must be protected with the aluminum arrester, to give protection to all the rest? For example, if you have thirty stations, will the protection of ten of them with aluminum arresters protect the balance against internal surges?

E. J. Berg: I have purposely refrained from giving any theory for the action of these arcing grounds, because an incomplete theory is worse than no theory at all. I believe, however, that Mr. Taylor's theory will not apply. Referring to the diagrams showing grounding of one side of the open delta, you see that the transformer nearest to ground is subjected to a voltage which corresponds to 3.25 inches striking distance. At that time the striking distance across the outside transformer is 3.21 inches. If Mr. Taylor's theory were correct, the striking distance across this latter transformer would have been 2 inches.

It may be of interest to add that at the time of such an arcing ground not only are the end turns subjected to high voltages, but also to considerably greater current and correspondingly greater heating, than the other turns.

Regarding Mr. Waters' discussion: I tried, as you see from the paper, to overcome the difficulties discussed in the paper, by the use of reactive coils, but was unable to reduce materially the stresses incidental to these arcing grounds. This was true even when using a large number of coils, the turns of which were approximately one-sixth of the total number of turns in the transformer. These coils did not contain any iron, but they were of the same dimensions as the transformer coils.

Regarding the stresses on the end turns, Mr. Waters is no doubt perfectly right, but it may interest you to know that the company with which I am connected insulates the end turns of their high-potential transformers for one hundred to two hundred times the normal voltage. For very high-voltage transmission, it is likely that delta-delta connection will not be used, but instead the delta-Y grounded neutral, with which an arcing ground can not occur since such a ground means a short circuit, and consequently the line has to be cut out of service.

Percy H. Thomas: I wish first to say a word about Mr. Berg's paper. I think it is very important here to draw a distinction in arcs, so-called. The arc which carries a great deal of current, and in which there is no cooling of the arc between alternations, and the type of arc that is under discussion, in which apparently there is a practical healing of the gap between alternations, are entirely different things. I think it is clear that these rises of potential are produced by that type of arc which drops out between alternations; in other words, it is but little more than a constant repetition of the condition of the initial ground. It is pretty well known that when a transmission wire grounds, the charge from the capacity to ground starts oscillations in the system and produces waves and reflections of the same which may cause a rise of potential. This may have in the simple case a value twice normal, or in more complex cases somewhat more than this, on account of the presence of series inductance and on account of variations of line capacity, etc.; but the action does not give enormous voltages, and introduces no new principles or features. I think that point of view will explain a great many of the phenomena reported in Mr. Berg's paper. I do not find here anything new, in the way of a danger which we have not heretofore recognized. To any one who is familiar with experimental work of that character, the difference in the types of these arcs is easily detected. There is a rough, irregular sound in all arcs where there is a large percentage of healing in the gaps between alternations.

Another thing, which has tended to increase the apparent rise of potential reported in Mr. Berg's paper, is the fact that he has given jumping distances, and not voltages. This causes a considerable exaggeration with the voltage higher than 25,000.

I also wish to make one or two comments on Mr. Creighton's paper. I was going to raise the same point as was raised by Mr. Taylor in connection with the assumption of a lightning frequency of 3,000 alternations. I see the explanation is that the term " lightning " does not indicate the cloud lightning, but the natural discharge of the line. I want to protest against the use of this word "lightning." I do not think there is anything that will cause us more confusion than to use the term generally for all sorts of discharges in the circuit and also for all disturbances outside, as well as the natural lightning phenomena. If we could all get together and agree that we would give the word lightning a certain new meaning it would perhaps not be misunderstood. but we are writing for a great many people over whom we have no control and they will not understand it at all.

Another point: In regard to the word "static ", I wish to defend Mr. Berg. If there is one term that we need in the business, in electrical high-tension work, it is a general term to describe these disturbances which come from discharges or surges in the line, due to other than normally generated electromotive force. These disturbances are entirely different in their nature from the so-called dynamic electricity. I know of no word which anywhere nearly so well expresses the idea as the word " static."

Professor Steinmetz: Lightning.

Percy H. Thomas: The word " static " is used broadly at the present time with this significance. It is true, surges are not static electricity, but this seems to me a meaningless objection. I wish strongly to urge the general adoption of this term. No one will be misled, and it fills a long-felt want.

I wish to inquire of Professor Creighton, whether the use of salt, in perfecting ground connections using iron, would not be a pretty dangerous recommendation, on account of the corrosion. It is well enough for experimental purposes, to determine losses, but it seems to me would be undesirable for use in permanent grounds.

I wish to state that in the past I have been inclined to doubt the efficiency of overhead ground wires and their effectiveness, but at the present time I am pretty well convinced that ground wires give the best and almost the only hope of completely protecting transmission lines against lightning. The point I attempted to make in my paper, and which seems to have been taken too broadly, is that the particular experiments referred to in the paper have not proved that these particular ground wires were effective. If these ground wires are properly installed, I believe they offer a very promising remedy. The danger is, first, that as they are ordinarily used, ground wires are not sufficiently separated from the transmission wires, and lightning striking them will also jump to the wire itself; and second, that they are not so located that the lightning will always strike them first. There is always a probability that there is one transmission wire, or possibly two, which is at a lower potential with regard to the cloud than the ground wire itself. There will be a tendency for a discharge to pick out this transmission wire rather than the ground wire.

I cannot agree with Dr. Steinmetz that it is not possible to distinguish between the effect of a bound charge and a direct stroke of lightning. To my mind, this difference is vital, for the reason that the character of protection required will be different for the two types of disturbances. If it is a matter of a bound charge, you must have a static shield, which is difficult to obtain completely, but the intercepting of a direct stroke may not be so difficult. There can be no doubt that all these types of disturbances do affect the line, whether it is a bound charge, direct stroke or electromagnetic induction. The vital question is, which sort is it that punctures insulators and slits the pole? If we find which one of thēm does that real harm, we can then protect against that, and let the others go.

Mr. Vaughan's paper shows that there are a tremendous number of lightning disturbances which do not go over the insulators. I think a careful study of the paper shows that the attack which did the damage came from the air.

Mr. Osgood asks about the extent of the disturbances shown by the Taylor's Falls tests. There are two criteria: first, the individual stroke, which I believe is felt in severe form on only a very few poles, and second, the static waves in the line which are of limited energy and voltage but which travel all over the system. The evidence in Mr. Vaughan's paper and other evidence corroborates this.

I wish to protest against the statement that we find about three or four times on every occasion when we have a lightning-arrester paper, that this sort of data which is presented should not be taken seriously, that it will not do to infer too much from it, that we must reserve our judgment, that it is necessary to prove these things before people can accept them, etc. It seems to me that is a narrow view to take of the subject. If all had taken that view, we would know almost nothing about lightning at the present time. One or two examples from other branches of scientific work may be called to mind to show how untrue such a position is. Take the investigations of Hertz, who drew inferences from ordinary microscopic sparks in an exploring coil—the theory he built up has proved itself to be true. Our data is fully as illustrative. Take the case of radioactivity, the results that have been obtained from the study of very minute and apparently most insignificant measurements. Similar is the work of J. J. Thomson and others on the ionization of gases. All these were worked out from data naturally much more inconclusive than the data we have in lightning.

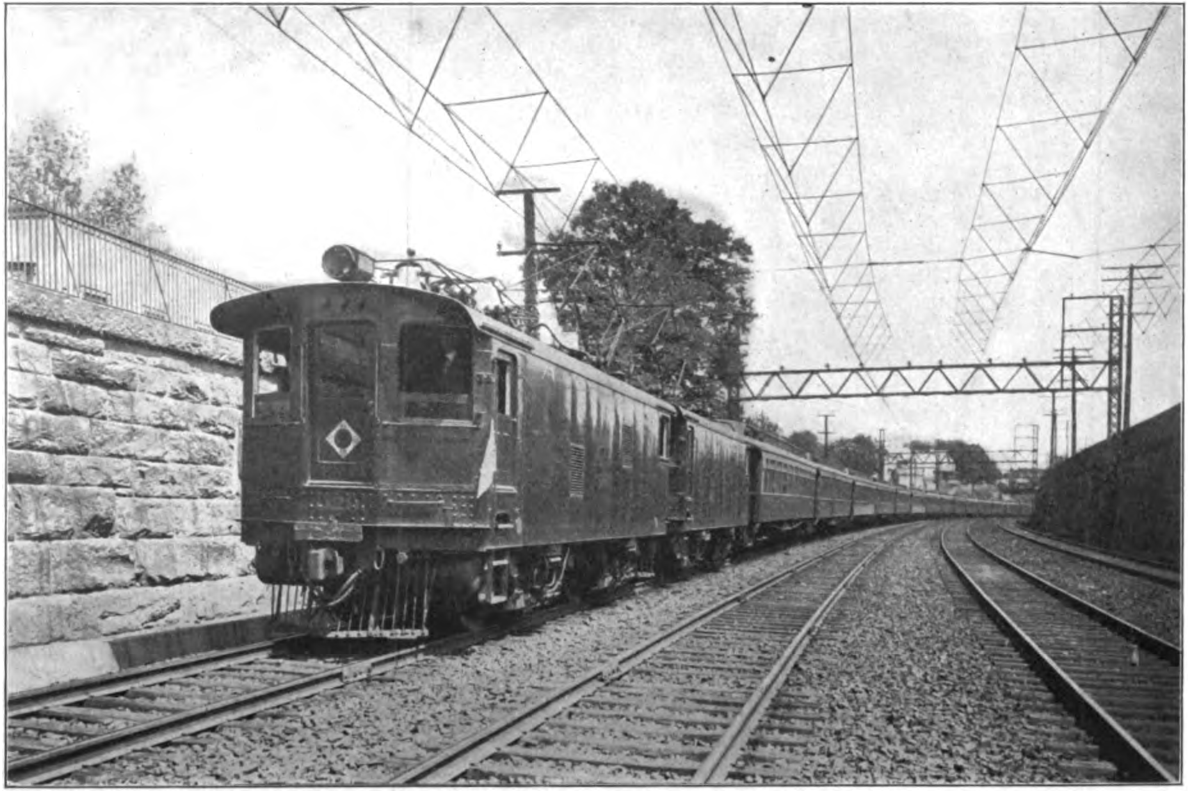
DISCUSSION ON "GRAPHICAL TREATMENT OF THE ROTATING FIELD." ATLANTIC CITY, N. J., JULY 2, 1908.

(Subject to final revision for the Transactions.)

Comfort A. Adams: This is not an easy paper to discuss, for although it presents many familiar phenomena, it presents them in a new language with which it takes time to become familiar. It is a very good kind of language, however, as it assists greatly in visualizing the problem in hand. This is of value, not only to the beginner in getting a picture of what goes on, but to the man who has to make the calculations, because when he can see the problem clearly in his mind's eye he is far more apt to get accurate and reliable results from his calculations.

There are, of course, numerous methods of attacking any problem of this kind with similar or identical results, but some methods are far more valuable because of their intimate connection with the physical side of the subject and this is true of the one presented by Mr. Hellmund. As to the comparative value of this method for the calculation of leakage, etc., I am not yet able to give an opinion, but it certainly is very interesting and throws much new light on several rather troublesome problems in induction motor analysis.

R. E. Hellmund: In regard to the belt leakage phenomena, the diagrams lead me to the conclusion that matters are more complicated than I had previously supposed. It occurred to me lately that the latter, unlike the other leakages, depends not only upon the magnetic dimensions, number of turns, etc., of the motor, but also varies largely with the secondary resistance. The belt leakage phenomena depends upon the current distribution of the secondary, and the secondary current distribution in turn changes with the secondary resistance. It may be shown, for instance, that in a squirrel-cage secondary with a resistance of zero, the current distribution is not even approximately sinusoidal but approaches closely to that of the primary, the secondary being assumed stationary. In this case the counter magnetomotive forces of the secondary are, at all parts of the circumference, equal and opposite to those of the primary. Therefore the belt leakage fluxes cannot exist. Assuming the other extreme; that is, a secondary of very high resistance, the current distribution in the secondary will be approximately sinusoidal, and the secondary magnetomotive forces are no longer distributed like those of the primary. A certain differential action; that is, belt leakage fluxes, seems therefore to be possible in this case at certain parts of the circumference. It will be of little value to discuss these questions more in detail at this time since I have not yet arrived at definite conclusions as to their practical importance.



New York, New Haven and Hartford Railroad Company.

A paper to be presented at the 232d meeting of the American Institute of Electrical Engineers, New York, December 11, 1908.

Copyright 1908. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

THE LOG OF THE NEW HAVEN ELECTRIFICATION

BY W. S. MURRAY

SYNOPSIS OF PAPER

Introductory

1. Object of paper.
2. Value of mistake.
3. Value of ignorance.
4. Facts—necessary to stable conclusions.
5. Effect of experience on decision.
6. Relation of steam versus electric traction.
7. The new chain—its old links.
8. The public.

Major Faults

1. Power house.
2. Insulation.
3. Circuit-breakers.
4. Line.
5. Locomotives.

Minor Faults

1. Generator burn-outs.
2. Distribution.
    - *a.* Multiple-track circuits.
    - *b.* Independent track circuits.
3. Contact wire.
4. Hard spots.
    - *a.* Hangers; *b*, section breaks; *c*, deflectors.
5. Signal wires.
6. Locomotive current collectors.

Log of Operation

1. Electric passenger service.
2. Electricity versus steam.
3. Train-minute delays; *a*, table; *b*, chart.
4. Serious failures—over 300 train-minutes.
5. Engine repairs—*a*. Table showing engines in shop.
6. Engine capacity—*a*. Table showing trailing loads in excess of guarantees.
7. Engine-mileage—electricity and steam compared.

The Electrification in Relation to Matters Other Than Traction

1. Telegraphs and telephones.
2. Public safety.
3. Foreign wires.

Commentary

1. Lightning protection.
2. Grounds.
3. Tell tales.
4. Train heating and lighting.
5. Fatalities.
6. Single- versus double-catenary construction.
7. Cross-catenary versus bridge bents.
8. Single-phase operation.

Conclusion

1. Alternating current and the engineer.

THE LOG OF THE NEW HAVEN ELECTRIFICATION

BY W. S. MURRAY

The object of this paper is to bring the actual operation of the New Haven single-phase electrification as closely as possible to those who are truly interested in its merits and faults. If the writer can feel that this object has been accomplished, the reward for the effort will be sufficient.

In advance of freely opening up the subject without mental reservation, it may be well to say that he is not unmindful of the adverse construction and criticism that will be placed by some upon the facts he intends to present. Having carefully weighed this, however, he has concluded that it should not be permitted to stand in the way of, or militate against, the sounder and analytical judgment of those intent upon a fair consideration of the facts as they exist.

The first intention was to make the subject of this paper " The Errors Made in the Electrification of the New Haven System ", but realizing what capital such an " admission " would make for those few who are inclined not to be fair-minded on this important matter, the title has been changed, and the body of the paper built upon a description of the faults, major and minor, that have been made, and their effect, by log sheet reference, upon operation. After all, the citation of " how not to do it " is far more valuable than " how to do it ". It may be at some sacrifice of pride to discuss one's errors, yet there is something so valuable in the exposition of an error that this, in itself, is ample compensation for its acknowledgment. There seems to be too, something altruistic about a mistake or " wrong "; for in its death there is born a " right ", and one can never really get on intimate terms with his mistake until its rightful complement has been substituted. After a railroad has changed from a steam to an electric schedule, the natural question immediately follows: "Is it a success?" The answer to this question involves almost an infinity of analytical judgment. Electrical engineers have no greater professional or moral responsibility before them than the presentation of all available data, in which will be included information of pertinent application in the solution of the vast electrification problems of to-day. To those entrusted with the responsibility of such decisions is due every possible help and light. Engineering conclusions are based on 5 per cent. theory and 95 per cent. practice; practice being made up of experience and an acceptance of existing allied conditions. We want nothing unless we know all about it before it is ours. If we are wise, we should not be so particular about its merits as its demerits. Perfection cannot exist. This applies to electrification as to other things.

The duty assigned to the engineers of the New Haven railroad was to provide for the electrical operation of their trains. At the early period of April 1, 1905, when we settled down to this responsible task, the data in the field, upon which to base real conclusions, were about 5 per cent, in comparison with the experience now available. If " Ignorance maketh the brave " I can only say that I am more than thankful we were so ignorant at the outset. I do not believe that this remark will need any explanation here. Could we have read the history of our errors, rather than have made them, I question whether we would have had the temerity—though I confess our convictions would have been the same—to ask the president of the New York, New Haven & Hartford Railroad Company to put up with the criticism, abuse, and unfair remarks that have been made by those ignorant of the facts, and of others who, perversely, were intent upon their own selfish, narrow course with manifested abandonment of all purposes to acquaint themselves with the nature, the scope, and the possibilities which lay easily within their knowledge, merely by the asking. To-day I am thankful to say, this negative attitude is giving away to the alarm made manifest by undisputed facts, which demand their own recognition. I have no personal desire to make any other engineer think as I do. If he sees the facts I see them, then we will vote alike. To those who may be interested in my conclusion in regard to the New Haven Railroad electrification, I can simply say that if I were in favor of its use three years ago, that now, standing on the more stable ground of experience, particularly in regard to the department of faults, I am doubly in favor of it to-day. I shall, of course, be interested in those who share this opinion after reading this paper, but I shall be doubly interested in them if their conclusion has not, in the slightest degree, been influenced by my own, but has been formed entirely upon the contemplation of the faults severally cited. And let me quickly add I shall be equally interested in those who honestly disagree with this opinion.

Unlike steam traction, where the number of links in the delay chain is but one, electric traction has its delay chain composed of three links; namely, the power house, line, and locomotive. A failure in anyone of these links may produce train delay or delays. Measured by the degree of their seriousness, these links, in the order of their effect on delays, may be mentioned in the order given. This is, of course, immediately apparent in that the power house affects all operation; the line, a considerable portion of the trackage, involving, possibly, several trains; and the locomotive is usually confined to its individual troubles, only infrequently affecting following trains. This order naturally has application to all forms of electrification, direct current, single phase, or polyphase.

In the conception of the form of power house, line, and locomotive to be used in the New Haven system, ignorance and lack of experience led those pertinently interested in its success to believe that while the chain of power generation, and its transmission and utilization for traction, was of a new character, that its links, however, were made up of principles long recognized and reliable. They were right in this conclusion, except that it did not include certain phenomena which could not have been anticipated, due to the combination of these old principles in the form of this new chain. For example, there was nothing particularly disturbing about an 11,000-volt 25-cycle, three-phase power house, from which was to be taken most of the power from one of the phases generated; or of a 300-ft., 11,000-volt, single-phase transmission line, from the terminals of which the same voltage was to be distributed, east and west, along the right-of-way of a railroad; or of a locomotive with a transformer installed upon it to take 11,000 volts and step it down to 600 volts to supply 300-volt single-phase railway motors. Power houses of this character have been designed the world over, except perhaps that single-phase current in the amount to be utilized had not been used elsewhere. Transmission lines of 60,000 volts had been in constant use. And, except that there was a moving contact in connection with the current that was to go to the step-down transformers on the locomotives, transformers of many times the capacity and voltage were in universal use. The single-phase motor, indeed, may be said to have been new so far as the size required for the New Haven service is concerned, but tests made upon smaller units demonstrated beyond peradventure its tractive qualities and showed its characteristic curves to be closely similar to those of its prototype, the direct-current motor. This reasoning, in close consideration of each class of apparatus, per se, has proved itself correct, and such irregularities as have existed in the initial electric service, which the New Haven road offered to the public, while deserving the condemnation which the public can unfailingly offer, have been due to the ramification of a series of faults that have developed entirely outside the zone of previous experience. The delays (and public criticisms of them) have followed even into this late day, when the electric service is far better than the steam service it has replaced. It has occurred to me that certain engineers, who are unbelievers in the single-phase system, may interpret this paper as an apology. To them I would say, as I do to the public, it is an apology for having delayed any of their appointments. To others, it is needless to add that the citation of these troubles is given in the hope that they will, as they easily can, avoid them in the future.

THE SERIOUS FAULTS

Power house. The electric power supply for the New Haven road is derived from four 11,000-volt steam turbine generators. three of which have an electric capacity of 3750 kilovolt-amperes single phase; the fourth unit consisting of a 6,000 kilovolt-ampere, three-phase generator, which can also supply single-phase current to the system.

Although the generators as originally designed were made exceptionally strong, and particular attention paid to their insulation, due to the necessity of grounding one phase, it was found that the utilization of so much single-phase current from a three-phase star-wound generator produced a stray magnetic field completely out of the path of normal lamination. As a result it was impossible to develop for continued operation more than 66 per cent. of the normal rating of the generators. Overloads of any character produced abnormally rapid heating, making such operation dangerous, although the generators were guaranteed to carry 50% overload for two hours, and 100% overload for two minutes in order to meet the sudden drafts of currents required for a schedule such as exists on the New Haven road. Indeed, at the very start the actual drafts of current showed that the generators must meet imperatively the guarantees as to normal and overload capacities if the electrification were to be successful. These, then, were the power-house conditions that confronted the New Haven road on beginning the work of propelling alternating-current trains. The power house being the heart of an electric system, to add more would be to say less in describing a critical situation.

I trust it is not to be my pleasure to meet the prophet, who says, "This could have been anticipated." Suffice it to say that after three unsuccessful attempts at complete correction, each, however, affording some constructive results—months being absorbed in the dismantling and readjusting of the parts of these generators—the final attempt was successful and the generators are to-day operating in the power house, fulfiling the guarantees mentioned previously. But this last mentioned fact is insignificant when compared with the valuable information that has been derived, which will permit all other generators to be manufactured without the fault described.

Line insulation. The years of experience which we have had in the study of insulating various voltages led to what was considered a very conservative insulation in the various parts of the line. Messenger cables had to be insulated from the intermediate trusses and at their anchor-bridge termini. The trolley copper conductor was suspended from the messengers and had to be insulated at points where it entered the oil switches on the anchor bridges. Trolley wires had to be insulated from each other at section breaks. On curves, both messengers and trolley wires had to be strained over the center of the tracks through the agency of pull-off posts at the side of the tracks, the pull-off wire being insulated between tracks and the pull-off column itself. Feeder wires had to be insulated from their supporting cross-arms and at points where they pass under highway bridges. None of these problems in insulation had the appearance of an especial character and, indeed, did the road-bed provide traffic only for electric trains, the problem would have been simplicity itself. A pressure of 11,000 volts being the prevailing dielectric strain, the problem was to provide sufficient insulation at all the points mentioned above.

Of the effect of steam locomotive discharges upon insulators, there was no initiative by which to be guided, and it became necessary to decide upon the factors of insulation that would be required. It was thought that ample provision had been made: it proved otherwise. Experience has proved that, in places, just double the amount is required. It was quickly noted that the greatest number of insulator failures occurred wherever the insulation was subject to the direct blast of the steam locomotive. To correct the difficulty, therefore, it was found necessary to double up on anchor insulators. The intermediate messenger insulators proved adequate and it was not found necessary to increase the impregnated stick insulation between trolley wires at curves, but wood stick insulators had to be added in series with the moulded material insulator between the pull-off wire and pull-off post. The original insulators on the anchor-bridge switches were made of moulded material and for them was substituted porcelain. It was not necessary to change the feeder insulators on the catenary bridge struts. While very little trouble has been experienced with the form of insulation used for supporting the feeders under highway bridges, it is anticipated that trouble will follow if this is not changed. The present form consists of the corrugated spool-type insulator, for which there will be substituted a regular porcelain double-petticoat insulator.

To-day, instead of line failures being the rule, they have become the exception.

Circuit-breakers. The momentary energy involved in a short-circuit produced upon a line fed by high power, high-speed turbines is very great. Under the sub-title "*Power house*" it was stated that the generators were operating under their guaranteed capacities. Internal heating, due to stray magnetic field, was the cause of the generators failing to meet their designed capacity. This heating was completely cured by the simple addition of a short-circuited winding surrounding the rotating member of the generator, similar to that used in the well-known squirrel-cage type of induction-motor rotors. It is interesting to note here, however, that while the heating is entirely eliminated by this short-circuited winding, its effect on the occasion of a short-circuit is to allow more current to flow. This tendency, however, is controlled by a method later to be described. In the New Haven system, as the current from the power house was fed directly to the line and from there to the locomotives without transformation of voltage by transformers, the inductive element to counteract the surging current was practically negligible; under these conditions there resulted short-circuits which no circuit-breaker apparatus then designed could be relied upon to take care of.

Here it is expedient to point out the very marked difference in operating conditions between circuit-breakers used on a system that is grounded and one that is not. In either case, it is, of course, good practice to ground the frames of all circuit-breaker apparatus. In the case of the grounded system, this virtually brings one terminal of the generating system directly to the frame of the circuit-breaker; with the other terminal of the system connected to the jaws (contactors) of the breaker, it is readily seen that on the occasion of a heavy current surge, due to short-circuit, should the arc extend itself through the walls of the oil tank (wherein the circuit is broken), this would be a direct leakage to ground establishing a short-circuit around (or in shunt) to the circuit-breaker jaws, which action, of course, renders the circuit-breaker useless, and subjects it to the damaging effect of the arcing locally produced until interrupted by another circuit-breaker in series with the circuit. On the other hand, where the system is not grounded, even should the walls of a circuit-breaker be broken down, as explained above, there would be no electrical connection (unless the neutral be grounded) between the circuit-breaker frame and the generator, and thus no return path for the current. I desire to draw particular attention to this point, for while the circuit-breakers used in our case open short-circuits, since the current surges have been practically eliminated, I believe that the lining of the oil tanks should have an especially high insulation factor on grounded systems.

The failure of circuit-breakers, either in the power house or on the line, naturally produced train delays of large or small magnitude. It was difficult to believe that these large circuit-breakers were incapable of taking care of the short-circuits, and some time was wasted in thinking this way. Therefore, we reluctantly but surely arrived at the conclusion that the conditions would have to be changed.

The remedy was simple. Instead of feeding the main line

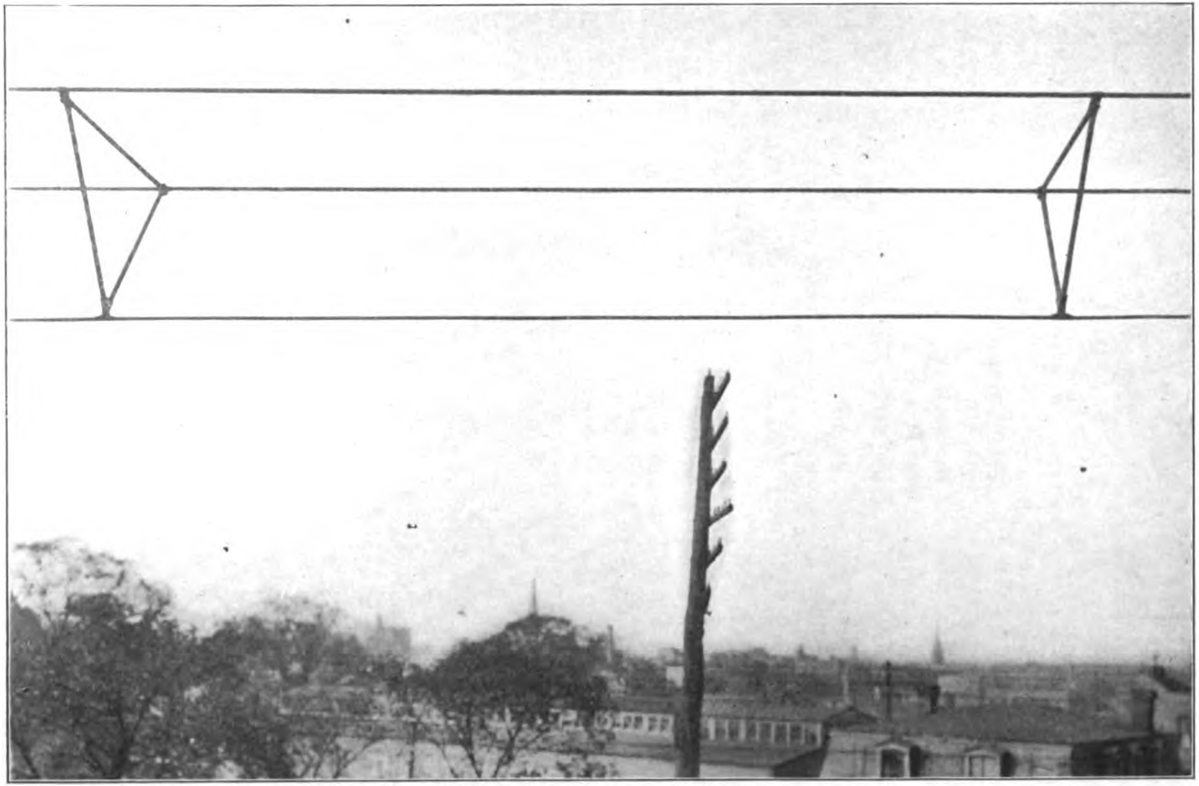


FIG. 1—Original copper trolley suspension

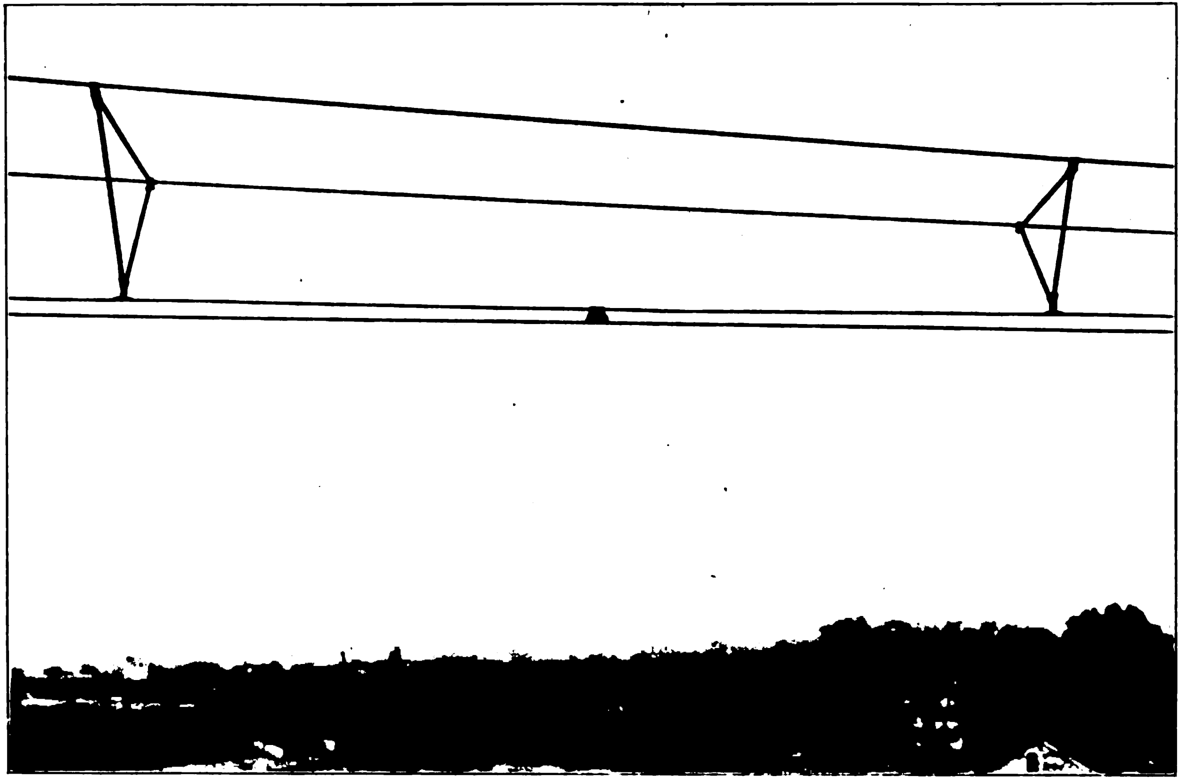


Fig. 2—Auxiliary steel contact wire suspended from original copper trolley wire

with a direct transmission straight from the power house busbars to the trolleys directly opposite the power house, the current was fed into the line over feeders connected to it at Port Chester and Stamford. By the introduction of this ohmic resistance, amounting to not more than 2 per cent. normal drop on the system, we were immediately released from the disastrous effect of short-circuits on our circuit-breaker apparatus. Instead of losing as many as half-a-dozen circuit-breakers in a day, not that many were reported out of commission for a month, and, of course, they were not damaged to the extent as the others nor did they cause any serious delays.

For the feeder resistance, above described, there has since been substituted impedance coils installed in the leads of the generators. These coils act as shock absorbers, protecting the generators. Later, it is to be expected that there will be installed a circuit-breaker across the terminals of these impedance coils, which, for normal operation, will shunt the current through them, the breakers opening under stress of abnormal flow of current and automatically closing when normal conditions are restored.

Trolley wire. In the month of May, 1908, it became evident to us that within at least one month from that date, if some change were not effected in the contact wire, that the New Haven electric service would cease. While this truth was so plain, it may be best described by the fact that daily reports were showing that the copper trolley wire was breaking at various points; and where it was not broken it had become so badly kinked at the hanger points that it was impossible to operate electric locomotives upon the line without serious arcing. This resulted in violent surging on the locomotive transformers, and, at times, on account of the extremely poor contact of overhead shoes on the line, in reducing the voltage to such a low value as to prevent a sufficient supply of power to enable the locomotive to perform its schedule. An examination of the hard-drawn copper trolley wire throughout its length proved that even after only a few months operation upon it, its cross-section had been so materially reduced as to point to its short life with a continuance of operation upon it. Especially was this true in the vicinity of the many low highway bridges where the trolley wire approaches the bridge on a two per cent gradient. This fault and dilemma were indeed serious. The cause of the difficulty was perfectly apparent; namely, the hard spots in the line which existed at the hanger points.

Many suggestions were offered. None of them, however, offered the speedy installation that was paramount. Mr. McHenry, vice-president of the New York, New Haven & Hartford Railroad Company, made the suggestion that an auxiliary wire be suspended from the present copper wire (Fig. 2) by clips at its midpoint between the hangers, and followed up the suggestion that this auxiliary wire be made of steel, of the same cross-section as the 0000 grooved hard-drawn copper above it. It took two weeks for the manufacturer to draw two miles of this wire. It was installed immediately upon its receipt on the main line between Port Chester and Harrison. On the night of its completed erection a special seven-car train with two locomotives was operated upon it for several hours. Previously to the installation of the steel wire there had been installed a section of hard alloyed wire suspended in a manner similar to that of the steel. The electric train was operated upon them both, officials from both the railroad company and the contracting company being on hand to note their comparative merits. It was the general consensus of opinion that there was less sparking on the hard wire, and the general tendency was towards adopting that rather than the steel. Though admitting that the operation was better, the steel seemed to be of an entirely satisfactory commercial nature, and all present finally concurred in this conclusion. It is undeniably true that hard alloyed wire would, from a purely operative point of view, be the better of the two, and yet the commercial aspect, which would naturally include its cost, had to be considered, particularly in reference to so large an immediate order as one involving 100 miles of single-phase electric trackage. Again it is important to note that the steel, besides having the advantage of being a cheaper, harder, and stiffer wire, also possesses a lower coefficient of expansion and higher elastic limit, especially valuable characteristics for the service desired. We found that we would be considerably delayed in the delivery of the steel, but an immediate order of 20 miles followed by another for 40 was placed, and as much hard alloyed wire put up as could be obtained between the date of the conclusion to use the auxiliary wire and the final arrival of the first shipment of steel. The auxiliary wire construction on the main line, as described, prevails throughout the whole system, except at the approaches of and under a few very low highway bridges, where the contact system consists of two wires strung in the same horizontal plane.

The New Haven trains have been operating now on the auxiliary wire for several months, and absolutely no kinking has been noted at the hanger points, with the attendant result of a smooth and almost sparkless overhead contact.

Locomotives. There were originally purchased 35 locomotives, which was considered an adequate number to take care of the New Haven passenger service. These locomotives, considered *per se*, were rated on a half-unit basis. That is to say, the half unit was designed to handle about 75 per cent. of our trains, the remaining 25 per cent. to be handled by two units. Only a short experience in commercial operation revealed two important facts. The first one of a very encouraging nature, the second, decidedly otherwise. The first was the proof that the two main parts of the locomotive; namely, the transformer and motors, had sufficient capacity to more than handle the manufacturer's guarantees. The second was the discovery that many of the auxiliary electrical and mechanical parts of the locomotive equipment were not of equivalent capacity. The strength of the chain being measured always by its weakest link, it was immediately seen that the locomotives would be able to handle trailing loads in excess of their guarantees if the auxiliary parts were made of sufficient capacity to furnish the necessary current for the overload conditions. It was simultaneously apparent that more locomotives would be required to provide for an increase of train service and the reduction of time schedule, and an order was promptly placed for six additional ones; before accepting their design, however, a careful survey was made of all the component parts of the locomotives at hand, in order to determine the changes necessary to be incorporated in the six new engines. To accomplish this it was found necessary to make a number of electrical and mechanical changes, the nature of which is apparent in the following tabulation:

MECHANICAL	ELECTRICAL
Air Reservoir System. Revised.	*Ammeters.* Revised.
	Battery. Charging relay installed.
Boilers. Installed.	*Blowers.* Commutator slotted Waste rear bearing. Armature laminations ground. Bearing raised above center. Motor winding revised.

Mechanical

Stack hood removed.

Bell Rope. Installed.

Blowers. New design installed.
  Guide on present damper rod.
  Extra guard on shutter.

Bolster. Reinforced on truck.

Brakes. New release spring.
  Cylinder leads lengthened.
  Check nut on adjuster.

Compressor. Drip pans installed.
  Exhaust pipe installed.
  Air-cooled cylinder head.

Check-valve. In whistle pipe

Gauge. On oil tank.

Electrical

Controller. Bushing riveted.
  Shoe and trolley switch installed.

Circuit-breaker. Fused.
  Tank bolt secured.
  New type installed.

Compressor. Commutator slotted.
  Armature laminations ground.
  New governor installed.
  Bearing raised above center.

Cut-out Boxes. New drums.

Fuse. In alternating current heater circuit.
  New auxiliary fuse box (wooden.)
  Auxiliary motors separately fused.

Grounding switch. Installed.
  Control revised.
  Shutter in cover.

Heater switch. Shield installed.

Heater bus-bar line. Reinsulated.
  Couplers repaired.

Headlight. Adjusted properly.
  Porcelain switch installed.

Motors. Holders reinsulated.
  New cross—connecting leads.
  Housing asbestos lined.
  Linen tape on commutator end.
  Side commutator covers perforated.
  Perforated S. I. commutator covers.
  Field clamp bolt secured.

Motor-generator. New switch.

Preventive coils. Revised.
  Supporting frame revised.

Direct-current relay. Connection to "—S" switch.
  Washer installed.

Resistance. Insulated.
  Capacity increased.
  Connected ahead of motor.

Switch group. Revised shunts.
  Revised studs.
  Revised arc shields.
  Copper reverse switches.
  One-turn blowout coils.
  Air ports enlarged.

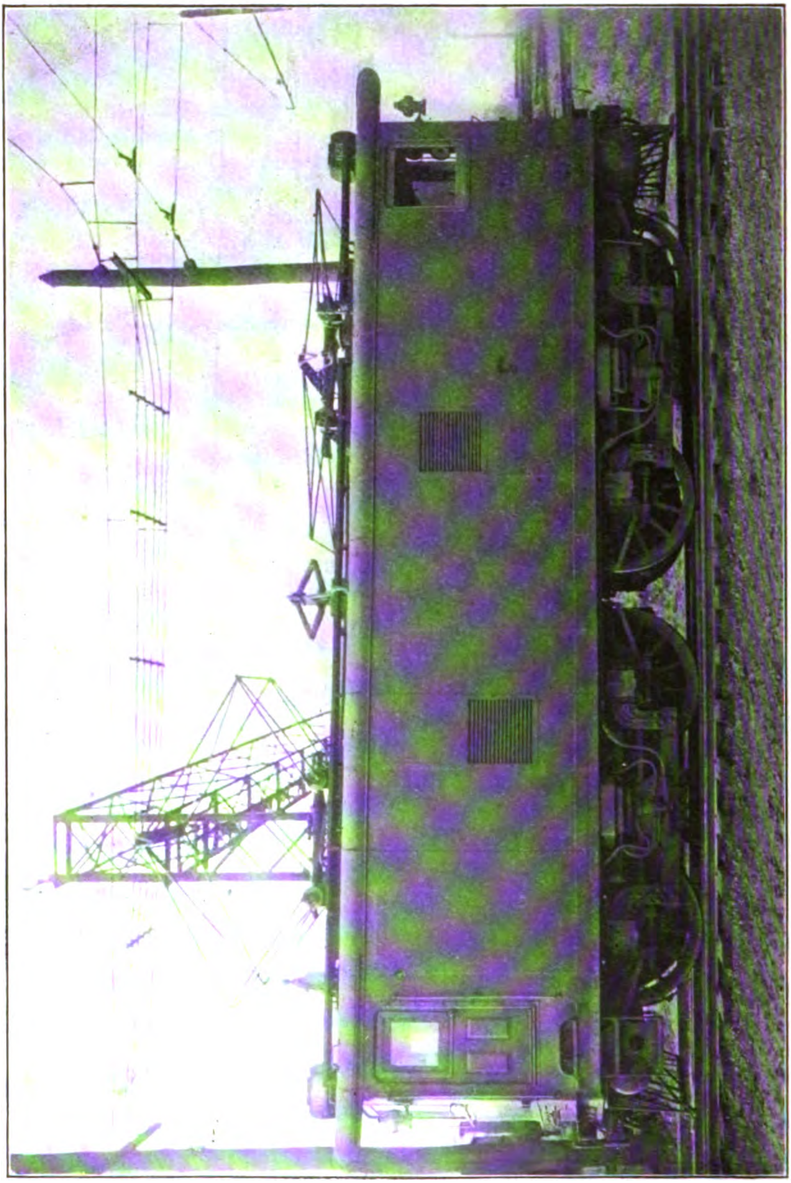


Fig. 3—Locomotive without pony trucks

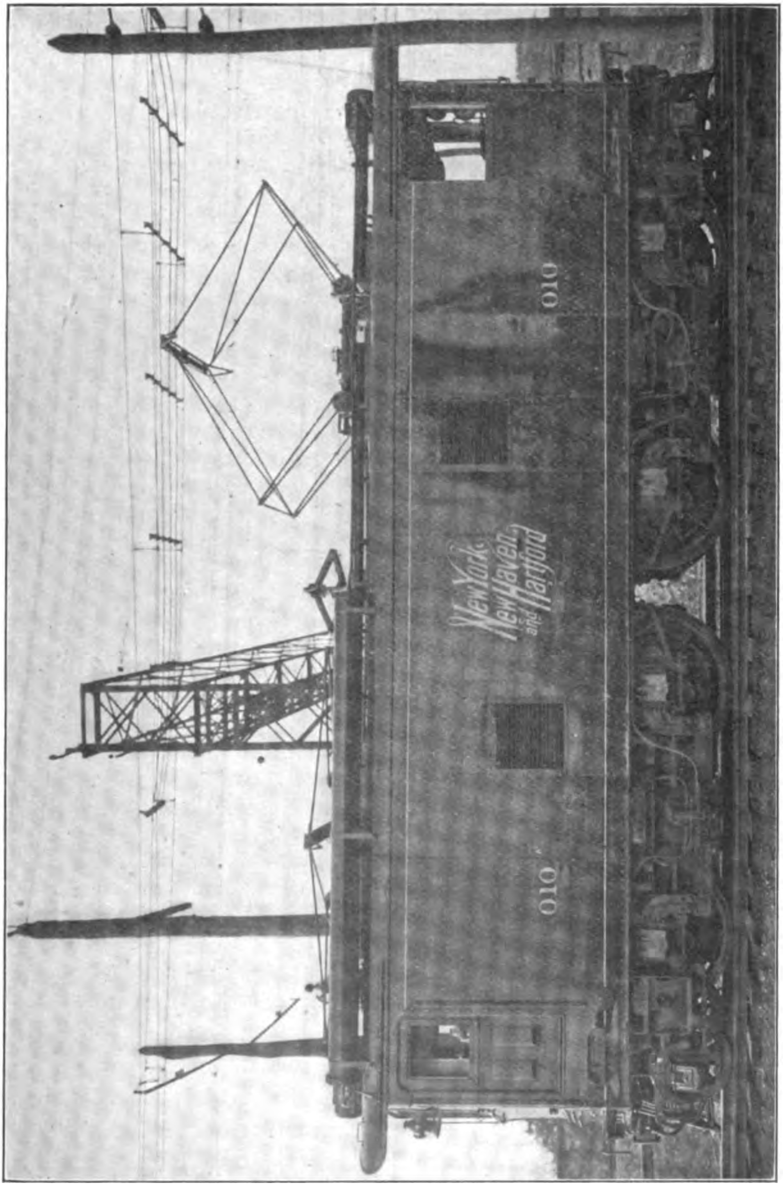


Fig. 4—Locomotive with pony trucks

Mechanical

On steam line.

Journal-box. Revised gibbs.

Quill-plate. Washers installed.

Running-board. On roof.

Semielliptic springs. 14 leaf.

Safety-valve. On control resistance

Safety-chain. Made heavier.

Torque rods. Heavy installed.

Uncoupling lever. Revised.

Pony wheels. Installed.

Valve. On oil line to boiler.

Electrical

Alternating current frames insulated.
Cylinder aligning set screws.
Reinforcing wooden strip.
Interlocked reverse switches.
Fitting alternating current switches.
Group covers perforated.
New B. O. coil pole piece alternating current.
Switch. Block on direct current case.
Main switch, connection modified.
Canopy switch handles insulated.
Shunt remounted. Direct current ammeter.
Trolleys. Control revised (alternating current).
Side bearing springs (alternating current).
Insulate back cross-rod (alternating current).
Shield for high tension lead (alternating current).
Spring shortened (direct current.)
Insulator filled and painted.
Temperature Indicators.
Third-rail shoes. M. I. bracket.
Pin replaced by bolt.
Jumper installed.
Shoe levers cut off.
Fuse boxes—Refitted.
Wattmeter. (Auxiliary) installed.

The most important electrical changes made were in the switch-groups and brush-holders of the motors. The former lacked carrying capacity and the latter sufficient insulation. To these shortcomings were due the greatest number of our first train delays. The most important mechanical changes necessary were the reinforcement of the truck bolsters and installation of pony wheels (see Figs. 4 and 3, respectively, for locomotive with and without pony wheels). The especial reference to these electrical and mechanical changes must not be construed as diminishing in any way the force of necessity of the others, as they were all considered absolutely necessary in order to preserve a low cost of electrical and mechanical maintenance.

With the exception of the installation of pony trucks, the six new electric locomotives arrived within five months of the date of their order. In their design were included all of the changes above specified. To be noted here is the marked value of the spring type of armature and field suspension begun with the New Haven locomotive motors, thus making flexible the entire motor suspension. Indications already predict that this arrangement in combination with the pony trucks will reduce materially the track and locomotive maintenance and repairs. To-day the reconstruction, as above described, has been effected on over 90 per cent. of our locomotives.

This last and serious fault with which we had to contend completes the major difficulties that were constantly threatening the regularity of electric service.

It seems to be the time and place, here, to draw attention to a point in design concerning the New Haven locomotives that has been so persistently misrepresented by those who seem to have been ignorant of the facts. The specifications upon which the locomotive units were purchased, as stated hereafter, were that each unit would handle a normal trailing load of 200 tons. The writer, by careful measurement of the weights of all the trains (trailing loads) in the New Haven service, found that they averaged 212 tons. It seemed good engineering that if 75 per cent. of the service could be handled by locomotives rated upon a basis of 200 tons trailing load, that that would be the correct locomotive unit size; using two units for the remaining 25 per cent. of the trains. To-day, three years after this decision, we find that 73 per cent. of our trains can be handled with single units, 27 per cent. requiring two units. The percentage is slightly different from the original, as the service is slightly heavier.

Coincident with the use of the first double-unit locomotive trains there was started a rumor that the New Haven locomotives did not have the capacity for which they were designed. To dispel this idea forever, I judge the best argument is to refer to Table X, wherein are stated the trains whose weights were in excess of trailing loads the locomotives were designed to carry.

I trust that the above clears up any erroneous ideas con-

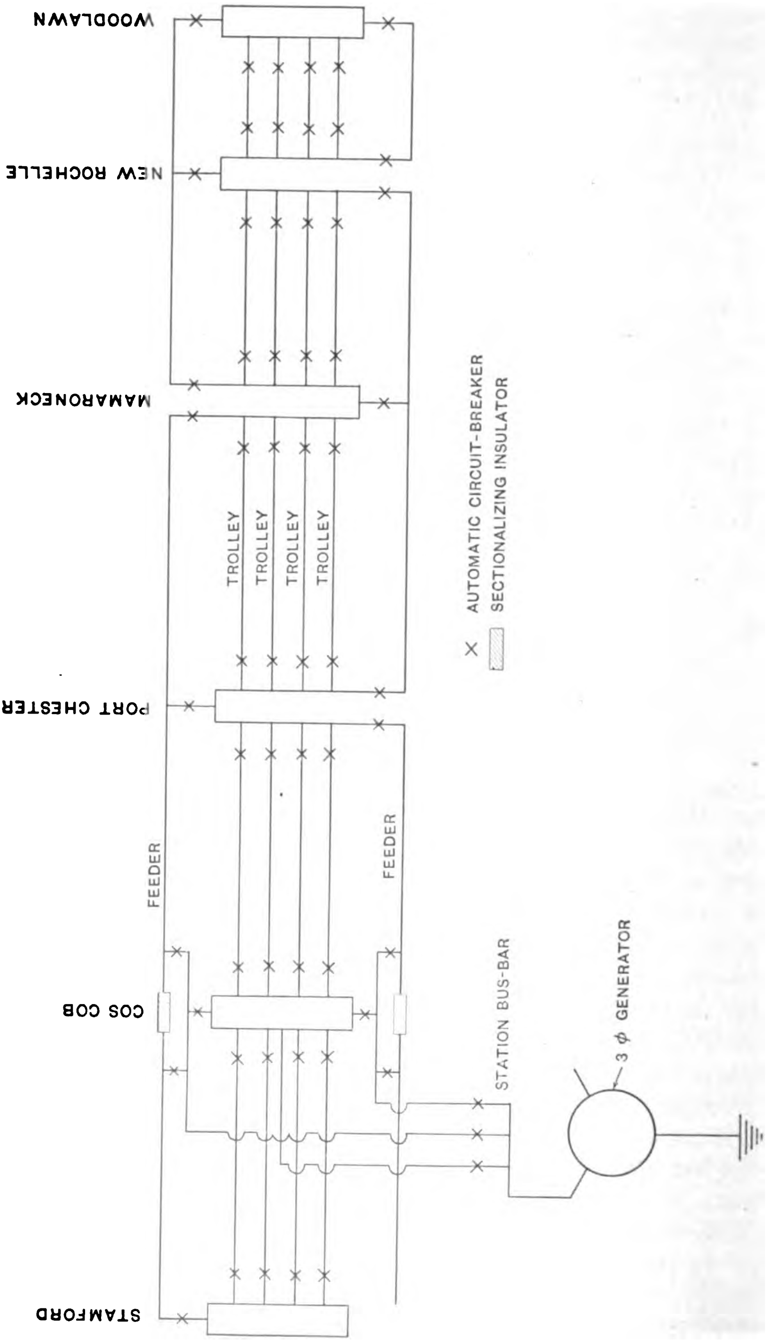


Fig. 5—Independent track circuits

cerning the capacity of the New Haven locomotives, and will justify the future double-unit trains entering and leaving the Grand Central Station.

Recapitulating, I believe my brother engineers will agree that with the coincident difficulties described in our power house, line, circuit-breakers, trolley wire, and locomotives, the work of instituting electric service was not exactly laid over a bed of roses. These are the serious faults the system possessed and the description of our method of elimination of them that I am glad to be able now to place before you. We cannot blame the public for making the complaints they have against the New York, New Haven & Hartford Railroad Company's electric service, for to the traveling public there is nothing so exasperating as a train delay. It is fitting here also to say how appreciative the engineers of the New Haven road feel for the calm and generous suspension of judgment on the part of those engineers who have reserved opinion until it could be based on facts which time only could so demonstrate as to permit presentation. There are many other little faults and difficulties here and there throughout the system, but the five described, though not fundamental in their effect, since they have been removed, were none the less the most serious.

THE MINOR FAULTS

Generator burn-outs. Previously to the rearrangement of the feeders or the installation of the choke-coils in the power station, the short-circuits that were experienced on the line naturally had a deleterious effect on the generators. The prodigious rush of current naturally produced severe strains in the armature windings, strains whose mechanical intensity was made manifest by the movements of the coils. Therefore, during this period of violent short-circuits, frequently the generator coils were grounded and burned out. Since the rearrangement of feeders or the installation of choke-coils, the violent short-circuits have disappeared and with them the damaging effects on the generators. It has been found advisable, from time to time, to connect different generator terminals to the line. By this arrangement the three phases of the generators are in turn worked equally.

Distribution. Although the arrangement of the line in its present feed and trolley connections (Fig. 5) effects the highest economy in loss of power by transmission, it is questionable to

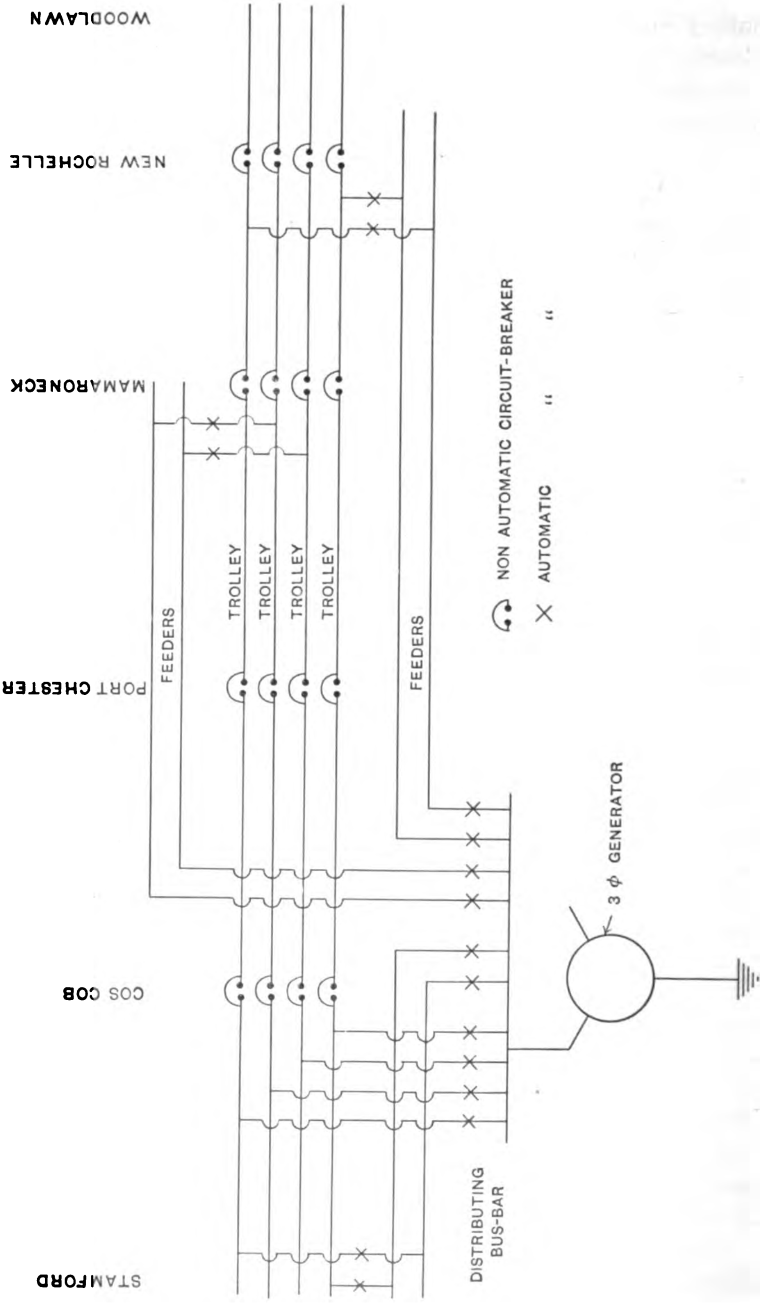


FIG. 6—Multiple track circuits

my mind whether this economy is worth some of the disadvantages which accrue from this arrangement. Until we had experienced the heavy current surges, due to short-circuits, it seemed reasonable that, should a short-circuit occur on the line, the two circuit-breakers which immediately fed that short-circuit would be the ones to respond. We were quite correct in this conclusion, but did not go far enough, as other circuit-breakers seemed to feel it their duty to relieve the situation and their location with respect to the correctly involved breakers was quite varied. Of course the ideal condition would be to have only the two breakers adjacent to the short-circuit open, as by this arrangement the voltage would remain on all trolleys except the one in which the ground is involved. This operation can be effected, and at the time of this writing an effort is being made to obtain these results in practice.

A less efficient method of line transmission (Fig. 2) than that described in the previous paragraph (using the same amount of copper for each case) is one in which each track has its own individual voltage supplied to it and is kept separate from the other trolleys.

Contact wire. While the auxiliary wire, as previously described, was the panacea of our difficulties, and has given an excellent account of itself since having first been placed in operation, it is fair to believe that even a more sparkless operation can be obtained from an auxiliary wire which, instead of being attached by a rigid clip to the overhead copper conductor, is simply suspended from it by a loop, thus permitting the contact wire to rise slightly as the upper pressure of the pantagraph shoe travels along its surface. The contact wire should be anchored by turn-buckles to permit slacking and straining of the wire in winter and summer seasons, respectively.

Hard spots in line. Irregularities in the contact wire may be due to two causes. First, those that exist in the wire as it is manufactured; secondly, those formed on account of hard spots. The former can be taken out; if not, they are usually ironed out in the course of the operation of the shoe on the trolley. The three principal sources of hard spots are derived from hangers, section breaks, and deflectors.

1. It has been shown in the foregoing how the hanger hard spots have been eliminated.

2. The original main-line section-break consisted of a rectangular impregnated wood frame suspended under the anchor

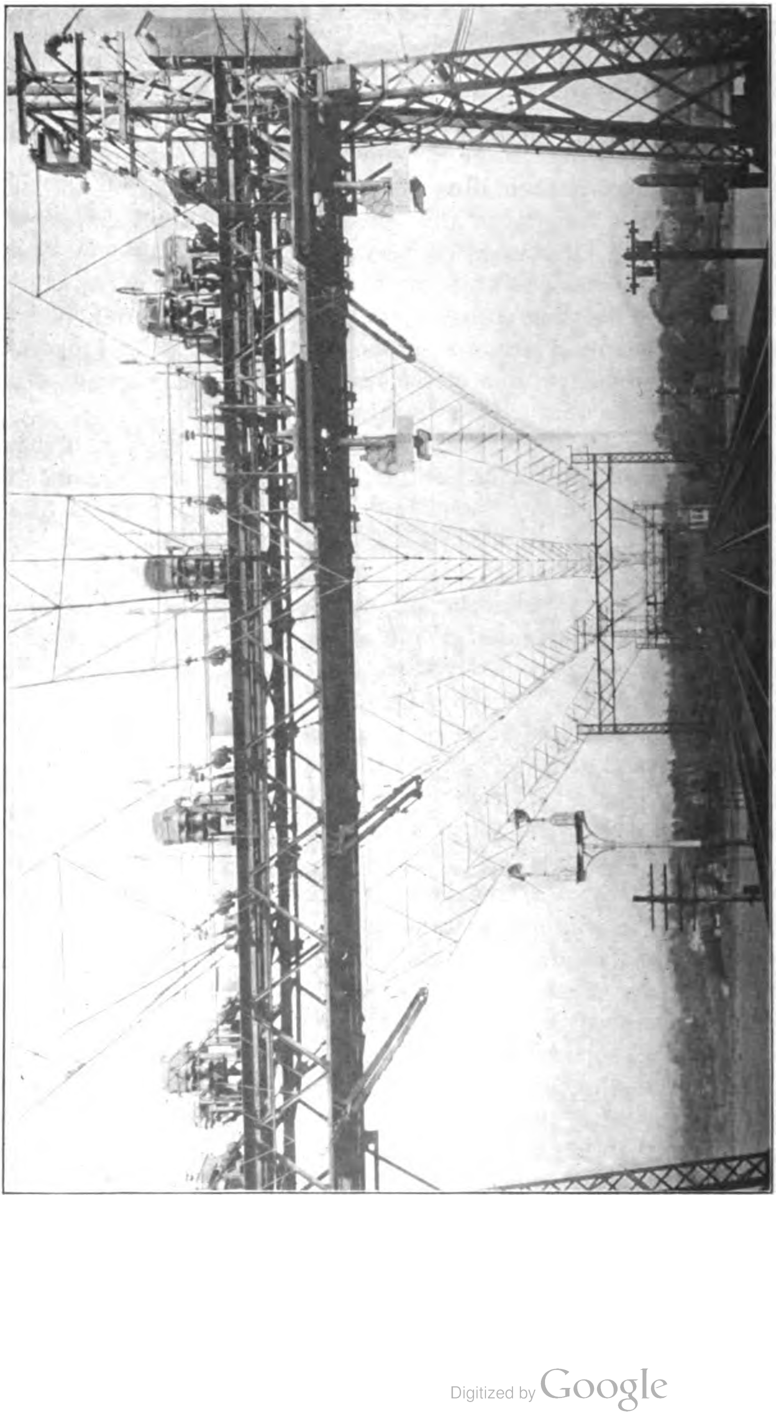


FIG. 7—End-on view of one new and three old section breaks

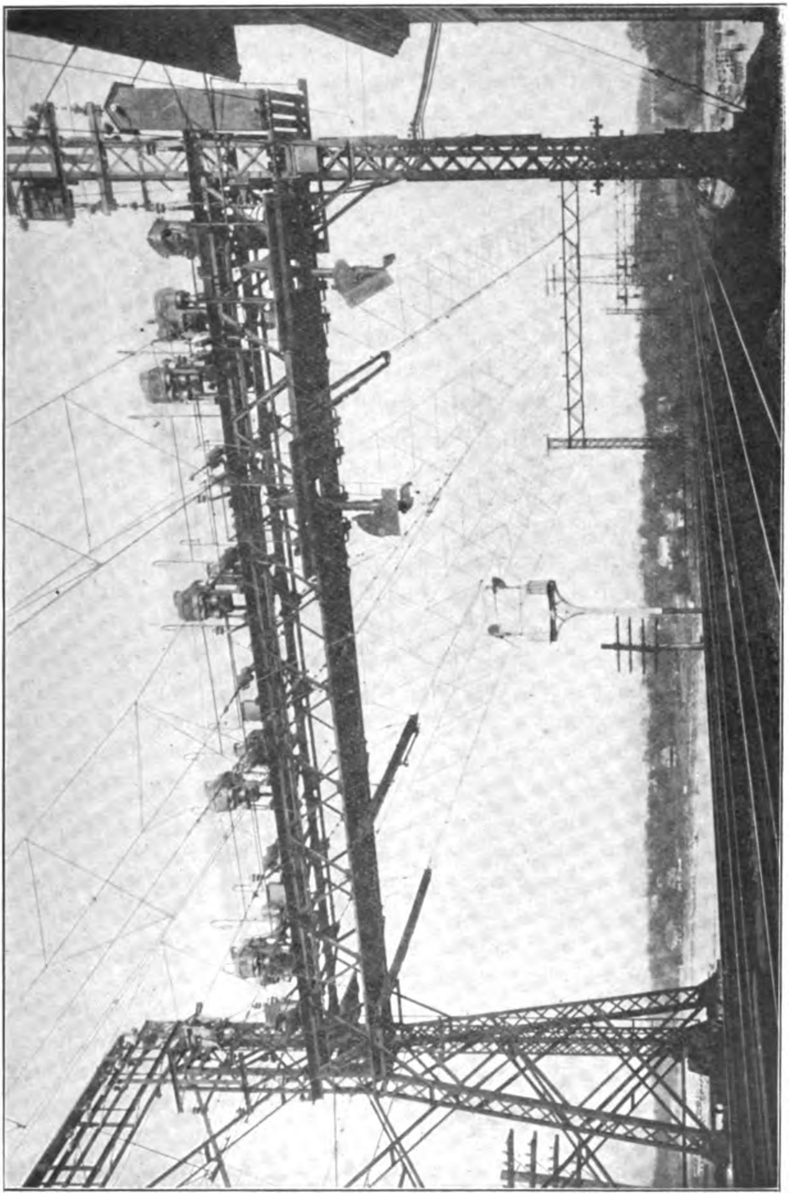


FIG. 8—Three-quarters view of one new and three old section breaks

bridges. The trolley wires were carried on opposite sides of this rectangle lapping, of course, a sufficient distance in the center so as to permit a short period of simultaneous contact of the shoe with both trolleys, thus preserving continuity of current to the locomotive in passing from one section to another. It was found that these rectangular section breaks were prone to get out of shape, introducing a very rough spot in the line, its effect being, on the passage of the shoe, to draw long arcs which frequently extended themselves to ground. Our new section break, Figs. 7 and 8, containing all the flexibility obtained by the auxiliary wire, has been constructed by simply staggering the messenger insulators of each trolley 16 in., thus permitting the anchor bridge trolley wires of the same track to pass at this distance. Each trolley wire is dead-ended to a wood impregnated stick insulator, supported by the messenger of its opposite section. By this arrangement practically all inertia is taken out of the section break and a sparkless passage between sections is obtained.

3. The auxiliary wire construction has been, of course, applied to the deflectors, and this has greatly reduced the tendency to spark at these points. In order to prevent the pantagraph shoe from engaging the wrong trolley wire at turn-outs on diverging tracks, the mesh construction of the overhead frog has up to this time been the only solution, but this method seems unduly cumbersome and even a greater improvement is anticipated than that secured by the application of the auxiliary wire.

Signal wires. The catenary bridge struts carrying the cross-arms for the by-pass or feeder wires, likewise carry the cross-arms upon which are installed the signal wires. The voltage placed on these signal wires is entirely distinct from the propulsion voltage, it being 2200 volts and 60 cycles. The proximity of the wires of these two systems has been the cause of short-circuits between them, resulting in double failures. It would seem that as the signal system should be so completely separated from the propulsion system, it should be installed on an entirely separate pole line. If, however, right-of-way conditions make it absolutely necessary that the supporting structures of the catenary system should support also the signal wires, then the two circuits should be made as distinctive as possible, the propulsion system having its wires on the cross-arms on the railroad side of the struts, the signal wires being installed on the opposite.

Locomotive current collectors. An efficient pantagraph shoe has proved itself a very difficult problem. The present cost is about .06 of a cent a locomotive-mile. We have made various experiments with aluminum, phono, copper, and steel rigid and spring-supported pantagraphs shoes. While this feature does not present a serious aspect, it is none the less a most interesting study. Shoe life is also seriously affected by the amount of soot deposited by the locomotives upon the overhead wire. While we have obtained mileages varying between 600 and 1500 miles per shoe with various types used, other roads of lesser speed and not subject to the effect of locomotive stack discharges, have obtained as high as 25,000 shoe-miles.

THE LOG OF OPERATION

Electric passenger service. So great was the demand for electric service that in July, 1907 long before we were ready, as the records of our operation have proved, the first commercial service was begun between New Rochelle and the Grand Central Station. With all speed possible the electrification was pushed eastward and local service was established from Port Chester in August, 1907. Local service from Stamford followed in October, and finally, on July 1, 1908, all through and local passenger trains were under electric schedule between Stamford and the Grand Central Station. It is, therefore, beginning from this date of July 1, 1908, that I have compiled data of our operation as taken from our records. We are not proud of it, but we believe that you now know of some of the obstacles that stood in the way of its immediate betterment at that time.

Comparison between steam and electric service. It had been the hope of the writer to be able, even at this early date, to make an absolute comparison between electric service and the steam service which it has replaced between Stamford and New York, including all passenger trains. On account of the speed restrictions that have been introduced on the electric service until all locomotives have been reconstructed with the new pony truck equipment, it is impossible to compare train-minute delays, for the reason that steam locomotives are permitted to make up time while to electric locomotives this privilege is denied. Later, when this restriction is removed, and especially after a period of time more extensive than that offered by the present comparatively short period of operation, these data can be presented. Particularly worthy of notation here in com-

TABLE I.

Train-Minutes Delay During July, 1908.

Day	Power house	Line	Locomotive	Total	Cause of delay
1	..	..	40	40	Third-rail shoe. Air hose, third-rail. Train line hose. One motor of locomotive grounded. Third-rail shoes.
2	..	..	34	34	Third-rail shoes.
3	..	..	20	20	Change-over switch direct current fuses
4	..	..	3	3	Pantagraph.
5	..	..	..	..	No delays.
6	..	15	..	15	Circuit-breaker.
7	..	..	..	..	No delays.
8	..	57	3	60	No power Direct current rail.
9	..	..	15	15	Direct current switch grounded.
10	..	13	..	13	Oil circuit-breaker. No power in Direct Current rail.
11	..	..	..	..	No delays.
12	..	..	16	16	Control current from storage-batteries low.
13	..	..	..	..	No delays.
14	..	..	..	..	Over 300 train-minutes.
15	..	4	72	72	Circuit breaker. Preventive-coil ground. Pantagraph. Third-rail switch. Motor man failure.
16	..	..	..	..	Over 300 train-minutes.
17	..	12	29	41	Insulator on foreign line broke. Change over switch Alternating Current coasting over gap at new bridge.
18	..	..	7	7	Direct current Fuses. Stopping on gap at bridge.
19	..	34	47	81	Line circuit-breaker. Pantagraph.
20	..	..	..	..	Over 300 train-minutes.
21	..	43	15	58	Line circuit-breaker. Transformer grounded on locomotive.
22	..	..	44	44	Alternating Current controller. Pantagraph.
23	..	..	41	41	Pantagraph.
24	..	..	3	3	Alternating Current controller.
25	..	..	124	124	Pantagraph. Direct-Current fuse. Alternating Current controller. Change-over switch. Motor grounded.
26	..	..	..	..	Over 300 train-minutes.
27	..	..	..	..	" " " "
28	..	..	30	30	Pantagraph. Grounded blower.
29	..	8	19	27	Circuit-breaker (line). Transformer-lead ground on locomotive.
30	..	16	..	16	Circuit-breakers.
31	..	..	21	21	Third-rail shoes. Alternating-current switch. Pantagraph.

TABLE II.

TRAIN-MINUTES DELAY DURING AUGUST, 1908.

Day	Power house	Line	Locomotive	Total	Cause of delay
1	..	5	3	8	Circuit-breakers (line). Third-rail shoes.
2	..	..	7	7	Heavy train.
3	..	..	12	12	Third rail shoes. Air hose. Pantagraph.
4	..	..	..	..	No delays.
5	..	12	10	22	Pantagraph. Motor ground. Third-rail fuses.
6	..	..	..	..	Over 300 train-minutes.
7	..	..	..	..	No delays.
8	..	..	..	..	Over 300 train-minutes.
9	..	43	..	43	Circuit-breakers.
10	..	220	28	248	Circuit-breakers (line). Locomotive circuit-breakers. Alternating current switches. Resistance lead.
11	..	57	26	83	Circuit-breakers (line). Change-over switch. Pantagraph.
12	..	5	2	7	Line circuit-breakers open. Hot tire.
13	..	..	..	..	No delays.
14	..	19	..	19	Insulator.
15	..	..	6	6	Control (Alternating Current). Direct Current circuit-breaker.
16	..	64	..	64	Insulator.
17	..	3	43	46	Circuit-breaker open (line). Ground. Direct current shoes. Pantagraph. Preventive coil ground. Direct current relay.
18	..	1	13	14	Insulator. Line. Air hose. Third-rail shoe.
19	..	..	..	..	No delays.
20	..	..	..	..	" "
21	..	..	8	8	Hot box. Alternating current control.
22	..	1	13	14	Insulator. Line. 18 in. water direct current zone.
23	..	5	..	5	Insulator. Line.
24	..	5	15	20	Ground on signal wires. Pantagraph.
25	..	32	41	73	Open circuit-breaker (line). Insulator (line). Hot box. Grounded motor. Third rail. Third-rail shoe.
26	..	..	73	73	Grounds developed by flood direct current zone
27	..	..	64	64	" " " " " " "
28	69	..	1	70	Turbine failure. Third-rail shoe.
29	63	..	22	85	Turbine failure. Engine dispatcher. Grounded Motor.
30	..	..	6	6	Heavy train. Low-voltage direct current.
31	..	..	14	14	Grounded compressor. Low-voltage Direct Current.

TABLE III.

TRAIN-MINUTES DELAY DURING SEPTEMBER, 1908.

Day	Power house	Line	Locomotive	Total	Cause of delay
1	..	..	4	4	Compressor. Pantagraph.
2	..	..	9	9	Air hose.
3	..	15	18	33	Line ground. Alternating current switch .
4	..	..	26	26	Alternating-current Control. Low-voltage direct current Alternating-current Control. Third-rail shoes—Ground Direct-current switch.
5	..	4	..	4	Open circuit-breaker.
6	..	..	3	3	Low-voltage direct current.
7	..	..	10	10	Third-rail fuses.
8	..	..	..	..	Over 300 train-minutes.
9	..	3	..	3	Line ground.
10	..	..	..	..	No delays.
11	..	..	7	7	Direct current switch ground.
12	..	..	19	19	Motor ground.
13	..	2	5	7	Line ground. Low-voltage direct current. Pantagraph.
14	..	..	8	8	Pantagraphs. Alternating current relay.
15	..	..	8	8	Preventive coil. Third-rail gap.
16	..	..	4	4	Preventive coil.
17	..	..	28	28	Locomotive wheels off track (pony truck).
18	..	..	..	..	No delays.
19	..	..	9	9	Preventive coil. Signals.
20	..	..	1	1	Third rail shoes.
21	..	..	2	2	Third rail shoes.
22	..	..	10	10	Hot tire.
23	..	..	32	32	Ground on reversing switch.
24	..	..	3	3	Hot box. Direct current shoes.
25	..	20	..	20	Circuit-breaker (line).
26	..	..	..	..	Over 300 train-minutes.
27	..	16	..	16	Grounded insulator.
28	..	4	8	12	Signal wires. Pantagraph—Third rail shoe.
29	..	3	10	13	Open circuit-breakers. Locomotive jumper grounded.
30	..	4	..	4	Line ground.

TABLE IV.

TRAIN-MINUTES DELAY DURING OCTOBER, 1908.

Day	Power house	Line	Locomotive	Total	Cause of delay
1	..	..	18	18	Nipple broken on train line pipe.
2	..	..	..	..	No delays.
3	..	..	3	3	Motor ground.
4	..	14	1	15	Splicing ear. Direct current shoes.
5	..	..	7	7	Pantagraph. Alternating current switch.
6	..	..	4	4	Change-over
7	..	..	9	9	Alternating current Switch. Air hose.
8	..	..	10	10	Direct current fuses. Third-rail shoes.
9	.	22	4	26	Circuit-breaker open. Direct current switch. Direct current shoes (third rail).
10	..	61	..	61	Open circuit-breakers.
11	..	..	..	..	No delays.
12	..	..	9	9	Pantagraph. Motor ground. Brakes sticking.
13	..	..	4	4	Direct current relay. Pantagraph. Low direct-current voltage.
14	..	3	..	3	Open circuit-breaker.
15	..	15	..	15	Line ground.
16	..	..	..	..	Over 300 train-minutes.
17	..	..	9	9	Pantagraph. Control direct current.
18	..	..	..	..	No delays.
19	..	..	10	10	Direct current circuit-breaker. Direct current control.
20	..	4	..	4	Insulator.
21	..	3	..	3	Open circuit breaker.
22	..	..	5	5	Grid resistance.
23	..	..	10	10	Air hose.
24	..	..	3	3	Third-rail shoes.
25	..	..	..	..	No delays.
26	..	70	19	89	Grounded insulator. Hot box.
27	..	54	19	73	Hot box. Insulator breakdown. Line ground.
28	..	..	63	63	Direct current resistance ground. Hot box. Pneumatic control.
29	..	31	82	113	Man failure. Grounded feeder. Direct current circuit breaker. Motor ground. Direct current switch ground. Alternating current switch. Third rail gap.
30	..	..	42	42	Direct current switch ground. Man failure.
31	..	..	12	12	Direct current relay. Motor flash-over. Pantagraph.

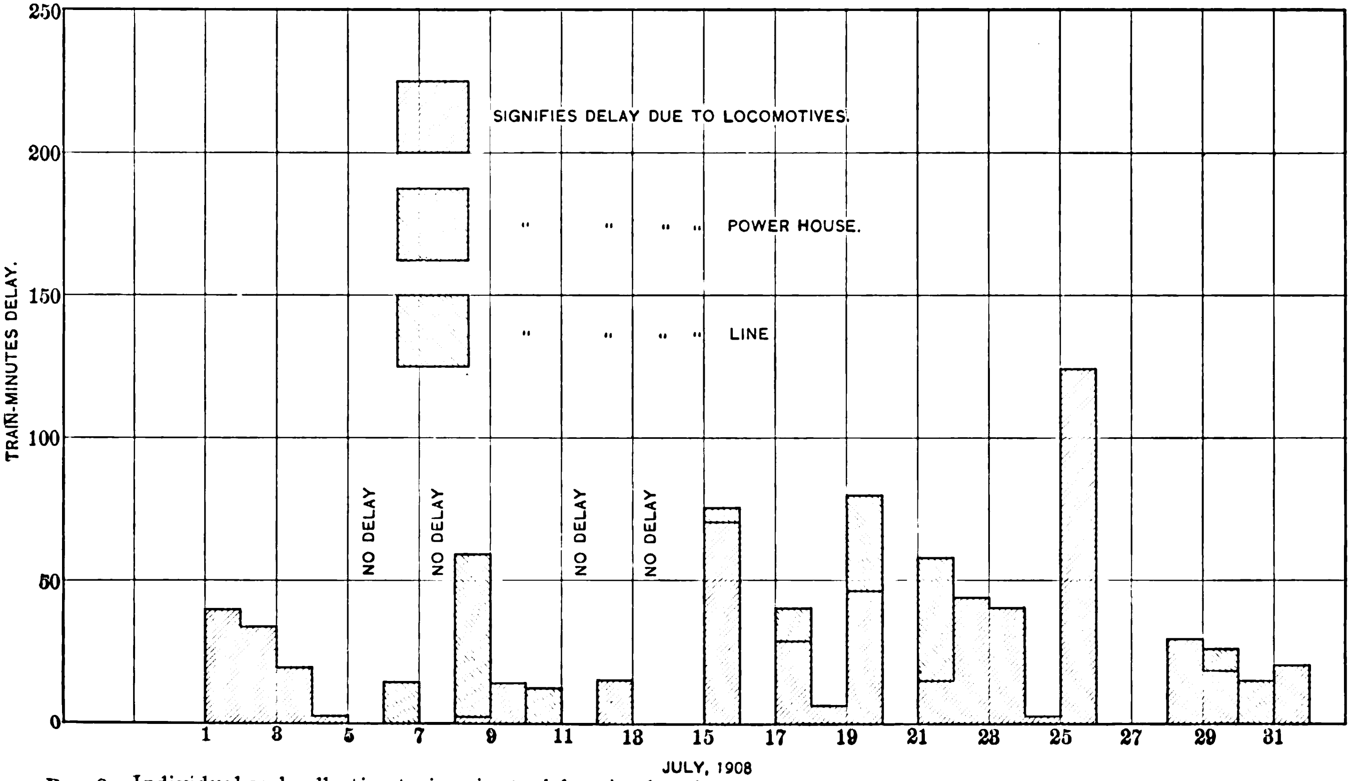


FIG. 9—Individual and collective train-minute delays in electric zone due to failures in power house, line, and locomotives

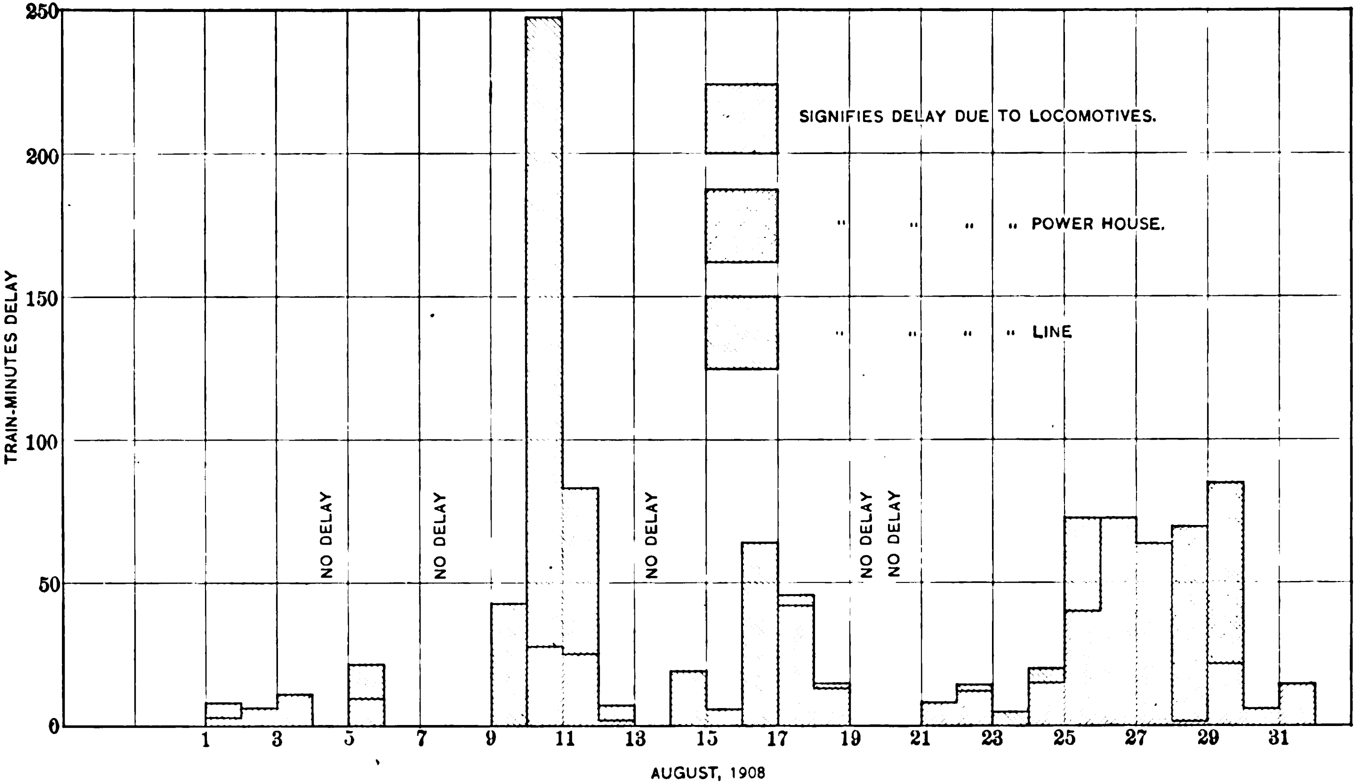


Fig. 10—Individual and collective train-minute delays in electric zone due to failures in power house, line, and locomotives

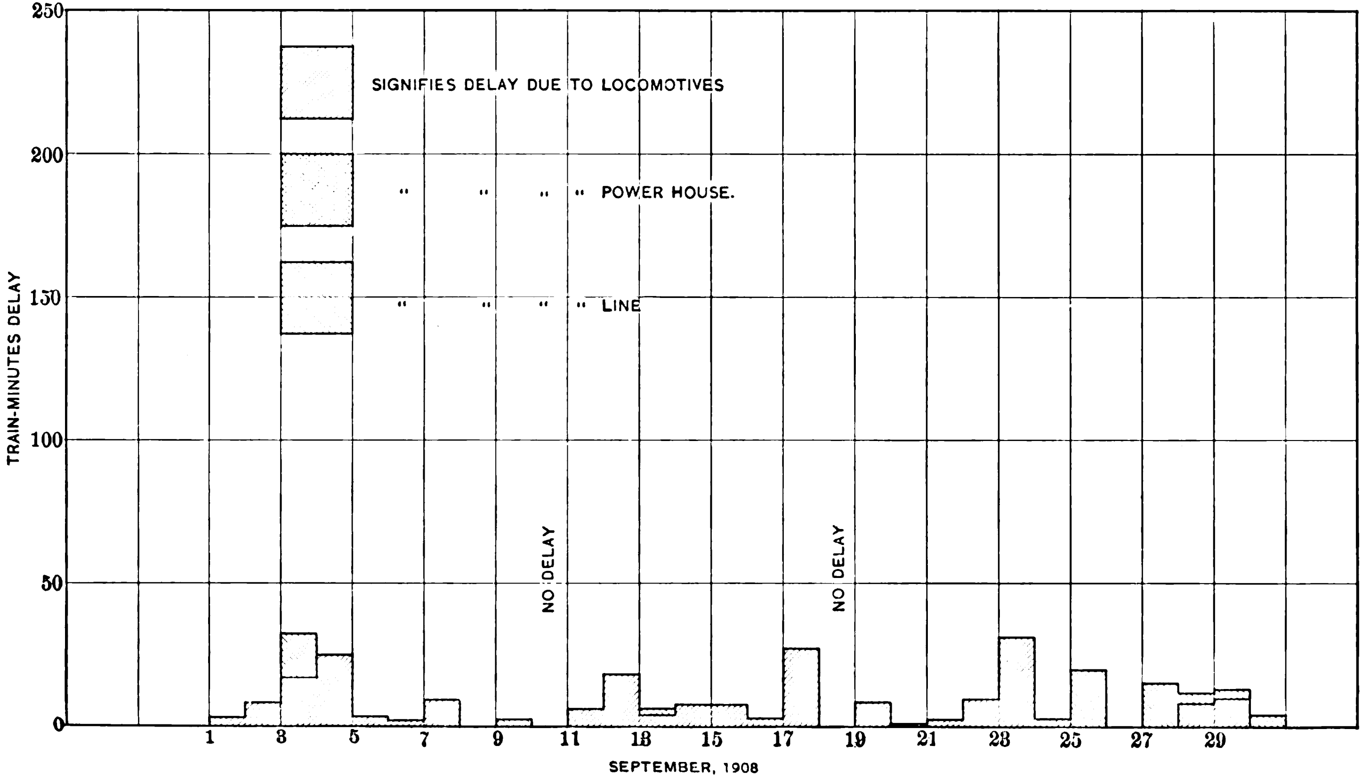


Fig. 11—Individual and collective train-minute delays in electric zone due to failures in power house, line, and locomotives

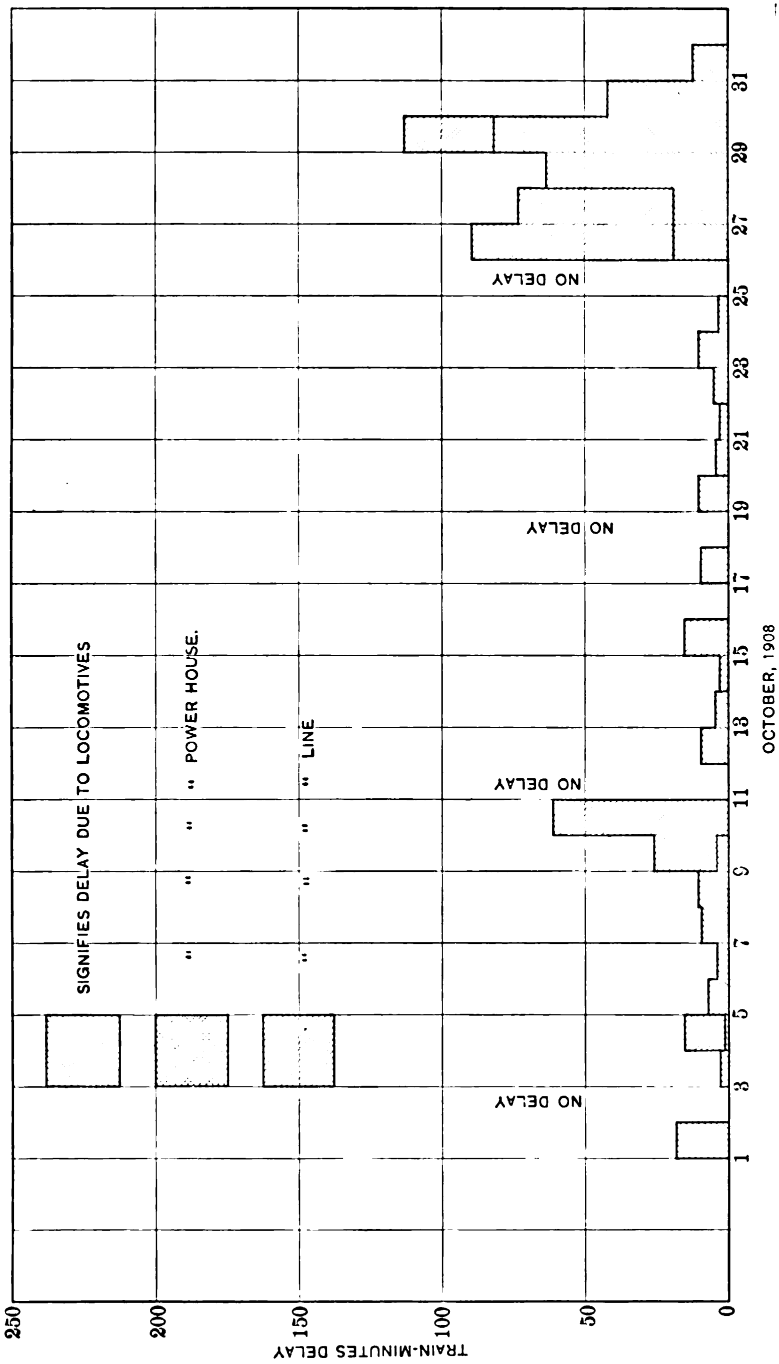


FIG. 12—Individual and collective train-minute delays in electric zone due to failures in power house, line, and locomotives

paring steam and electric service, it is necessary to bear in mind that while the operation of the power house does not differ from that of ordinary practice, there is a marked individuality (which initiative always brings), in connection with the operation of the line and locomotives. While every credit is due the present organization charged with the responsibility of line and locomotive operation, it cannot be forgotten that these two main links of the system are essentially new in their adaptation to the heavy conditions presented by the New York, New Haven & Hartford train service. Operation of this character is so far beyond the scope of previous experience that it was absolutely impossible to foresee and prevent all contingencies. The methods for the prevention of failure and delay were necessarily based upon the results of actual, practical operation.

Individual and collective train-minute delays in electric zone, due to failures in power house, line, and locomotive. Tables I, II, III, and IV are self-explanatory, and the charts shown in Figs. 9, 10, 11, and 12 that immediately follow represent graphically the data included in the tables.

The segregation of these failures based upon train-minute delays offers a quick and interesting comparison. It is to be noted that the last two months indicate a great improvement over the two preceding ones. From the chart have been taken the train-minute delays that have amounted to over 300 minutes per diem, which are treated separately in the following paragraph. My reason for doing this is to make the data inclusive of ordinary operating days, in order to get the monthly comparison of train-minute delays for what might be termed ordinary service. It is interesting in reviewing the " cause of delay " in this table to note that 90 per cent. of the causes are of an inconsequent nature, and might be reasonably expected when considered in the light of an initiative service.

Serious failures in system causing over 300-*minute delays.* It is to be noted that these failures are indicated by the dates of July 14, 16, 20, 26 and 27; August 6, and 8; September 8 and 26, and October 19. A description of the cause of one applies to all of them, except those of July 16 and October 19. In every instance, excepting the two dates mentioned, the tie-up was due to simultaneous failure of several circuit-breakers, due to a short-circuit, thus temporarily disorganizing the distributing system, preventing the electrification of trolley wires.

On July 16, the White Mountain Express left the rails just

TABLE V.

Locomotive Daily Reports, July, 1908.

Date	Reconstruction	Experimental & test	Trucks installed	Inspection	Repairs	No. of trains	Cause of repairs
1	1	..	..	2	1	136	Grounded motor.
2	..	..	..	..	..	142	
3	..	..	..	..	..	148	
4	..	HOL	IDAY	..	..	..	
5	1	..	..	..	1	81	Loose tire.
6	1	..	..	2	1	140	Loose tire.
7	1	..	..	2	..	135	
8	1	..	..	2	..	135	
9	1	..	..	1	2	135	Trucks (1) grounded switch group (1).
10	1	..	..	2	..	135	
11	..	SATU	RDAY	..	..	..	
12	1	..	..	..	3	69	Direct current shunt burned out (1). Tramming truck (1). Change-over switch grounded (1).
13	1	..	..	1	..	135	
14	1	..	..	..	2	135	Broken axle (1). Changing spring-hangers (1).
15	1	..	..	1	3	135	Broken axles (1). Short-circuited commutator (1). Grounded transformer (1).
16	1	..	..	3	1	132	Broken axle.
17	2	..	..	..	2	135	Trucks (1) slipped tires.
18	..	SATU	RDAY	..	..	..	
19	2	1	..	1	2	68	Hot box (1). Changing motors (1).
20	2	..	..	..	3	135	Trucks (1). Burned-out transformer (1). Change-over trouble (1).
21	3	..	1	..	4	135	Transformer grounded (3). Blower and compressor motors grounded (1).
22	3	..	1	..	..	135	
23	2	..	1	..	2	135	Motor trouble (1). Trucks.
24	2	..	1	..	1	135	Trucks.
25	2	..	1	..	1	137	Motor leads burned off.
26	..	SUN	DAY	..	..	..	
27	2	..	..	..	1	133	Motor leads burned off.
28	2	1	1	..	..	133	
29	2	..	1	1	1	133	Side motion.
30	1	..	1	1	1	133	Trucks.
31	1	..	1	..	2	135	Trucks (1). Loose tires (1).
Total	38	2	10	19	34		
Avg.	1.41	0.074	0.37	0.71	1.26		

TABLE VI.
Locomotive Daily Reports, August, 1908.

Date	Reconstruction	Experimental & test	Trucks installed	Inspection	Repairs	No. of trains	Cause of repairs
1	1	..	1	..	1	141	Trucks.
2	..	SUN	DAY	..	..	..	
3	2	..	1	..	2	135	Truck springs (1). Blower motors (1).
4	2	..	1	1	..	133	
5	1	..	1	1	1	134	Changing motors.
6	1	..	1	2	1	131	Changing motors.
7	..	..	1	..	2	133	Compressor grounded (1). Trucks and reconstruction.
8	1	1	..	..	2	136	No. 1 Main Reservoir leaking. Trucks and reconstruction (1).
9	..	SUN	DAY	..	..	..	
10	1	..	..	..	1	135	Trucks and reconstruction.
11	1	..	..	1	1	133	Trucks and reconstruction.
12	1	..	..	..	3	133	Grounded direct current relay (1). Loose tires (1). Trucks and reconstruction (1).
13	1	..	..	..	1	133	Trucks and reconstruction.
14	1	..	..	..	1	134	Waiting for wheels from Readville.
15	1	..	..	..	1	138	Waiting for wheels from Readville.
16	..	SUN	DAY	..	..	..	
17	1	1	..	1	2	133	Direct current shoe cables grounded. Waiting for wheels from Readville (1).
18	1	..	..	..	3	133	Circuit-breaker trouble (1). Direct current shoe cables grounded. Waiting for wheels from Readville (1).
19	1	..	..	..	1	133	Waiting-wheels. Readville.
20	1	..	..	1	1	133	Changing compressor.
21	2	..	..	1	..	133	
22	2	..	..	2	..	137	
23	..	SUN	DAY	..	..	..	
24	2	..	..	..	1	135	Grounded motor.
25	2	..	..	..	2	133	Grounded motor (1). Grounded armature (1).
26	2	..	..	..	9	133	Grounds, due flood, N. Y. Central zone.
27	2	..	..	..	5	133	M-1 switch-group grounded. Grounds, due flood—N. Y. Central zone (4).
28	2	..	..	..	2	133	Grounds, due flood—N. Y. Central zone.
29	2	..	..	..	2	141	Grounded motors (2).
30	..	SUN	DAY	..	..	..	
31	2	1	..	..	..	143	
Total	36	3	6	10	45	3502	(Total daily trains).
Avg.	1.39	0.11	0.23	0.39	1.73	135	(Average).

TABLE VII.

Locomotive Daily Reports, September, 1908.

Date	Reconstruction	Experimental & test	Trucks installed	Inspection	Repairs	No. of trains	Cause of repairs
1	2	..	1	..	..	137	
2	2	..	1	1	1	135	Grounded motor.
3	2	..	1	1	..	134	
4	2	..	1	..	1	139	Grounded motor.
5	1	..	1	..	1	148	Grounded compressor motor.
6	..	SUN	DAY	..	..	..	
7	..	LABO	R DAY	..	..	..	
8	2	..	1	..	..	143	
9	2	..	1	..	..	138	
10	2	..	2	..	..	138	
11	2	..	1	1	1	137	M-1 Switch grounded.
12	2	..	1	..	1	140	M-1 Switch grounded.
13	..	SUN	DAY	..	..	..	
14	2	..	2	..	..	129	
15	2	..	2	..	..	126	
16	2	..	1	1	..	126	
17	3	..	2	1	..	126	
18	3	..	2	1	..	126	Trucks.
19	3	..	2	..	..	130	
20	..	SUN	DAY	..	..	..	
21	3	..	2	..	1	130	Change-over switch grounded.
22	2	2	2	..	1	127	Change-over switch grounded.
23	2	..	2	..	1	126	Change-over switch grounded.
24	3	..	3	..	..	126	
25	2	..	2	..	1	126	Sharp flanges.
26	3	..	2	..	..	128	
27	..	SUN	DAY	..	..	..	
28	3	..	2	..	..	128	
29	3	..	2	..	..	126	
30	3	..	2	..	..	126	
Total	58	2	41	5	10	3295	(Total daily trains.)
Avg.	2.32	0.08	1.64	0.20	0.40	132	(Average.)

TABLE VIII.

LOCOMOTIVE DAILY REPORTS, OCTOBER, 1908.

Date	Reconstruction	Experimental & test	Trucks installed	Inspection	Repairs	No. of trains	Cause of repairs
1	3	1	2	..	..	126	
2	3	..	2	..	..	126	
3	3	..	2	..	..	129	
4	..	SUN	DAY	..	..	..	
5	3	..	2	..	..	126	
6	3	1	2	..	..	124	
7	3	..	2	..	..	124	
8	3	..	1	..	1	125	Sharp flanges.
9	3	..	2	..	..	125	
10	3	1	2	..	..	129	
11	..	SUN	DAY	..	..	..	
12	3	..	2	..	..	125	
13	3	1	2	..	..	126	
14	3	..	2	..	..	124	
15	3	..	2	..	..	124	
16	3	1	2	..	..	124	
17	3	..	2	..	..	126	
18	..	SUN	DAY	..	..	..	
19	3	..	3	..	..	125	
20	3	1	2	..	1	124	Turning flanges.
21	3	..	3	..	..	126	
22	3	..	3	..	..	124	
23	3	..	2	..	1	125	Grounded motor.
24	3	1	2	..	..	126	
25	..	SUN	DAY	..	..	..	
26	3	..	3	..	..	125	
27	4	..	2	..	..	124	
28	4	..	3	..	..	124	
29	4	..	2	..	..	124	
30	3	..	3	..	..	124	
31	3	..	3	..	..	126	
Total	84	7	60		3	3380	(Total week-day trains.)
Avg.	3.10	0.26	2.22		0.11	1250	(Average.)

TABLE IX.

Electric Locomotive-Mileage Data for September 5, 1908.

No. of Engine	No. of runs made	Main Line Mileage
01	In shop	
02	7	238
03	7	230
04	7	206
05	4	136
06	In shop	
07	4	111
08	3	102
09	8	256
010	8	264
011	5	170
012	7	196
013	8	245
014	6	188
015	8	247
016	5	162
017	In shop	
018	5	136
019	10	340
020	6	188
021	8	264
022	7	204
023	9	306
024	4	136
025	7	222
026	8	264
027	9	306
028	8	272
029	6	196
030	6	188
031	8	272
032	6	187
033	3	102
034	4	135
035	8	272
036	4	136
037	7	238
038	6	196
039	7	230
040	7	238
041	8	272
Total	248	8051
Average	6.5	212

Main line mileage does not include switching.
Maximum mileage made, 340.
Average mileage, 212.

east of Greenwich station, tying up both east-bound tracks, and causing excessive train-minute delays. Except for the electric rail bonds which suffered destruction, no other electrical apparatus was disturbed. One of the electric locomotives attached to this train was immediately returned to service, the other following it the next day after light repairs were made to its pilot and third-rail shoe mechanism.

On October 19, although the impedance coils in the generator station were in action, a ground occurring on the bus-bars of the anchor bridge directly outside of the power station, in combination with a defective circuit-breaker, produced a short-circuit which destroyed the operating mechanism of the breaker in question. This unfortunately occurred at a time when temporary connections had been made between the power house and line; on this account a serious delay was experienced in restoring the voltage to the line.

It is interesting to note that since the complete inauguration of electric service, the serious failures in the system have been reduced from five to one.

Engine repairs. Under " faults " is described the necessity in detail of our engine reconstruction. Since 100 per cent. service has been established, it has occurred to me that the shop reports concerning the daily number of engines which are out of service on account of repairs or for other reasons, would be interesting. On account of the reconstruction being done on the locomotives, it has been found necessary to give up on an average three electric locomotives at Stamford and three at New Haven, the new bogie trucks being installed on the engines at New Haven. Thus out of 41 locomotives we have had only 35 to handle the complete passenger service. This has resulted in requiring that the New Haven locomotives handle the service with virtually no spare engines. An examination of Tables V, VI, VII and VIII, under columns " Inspection " and " Repairs ", indicating how few have been the engines in the shop for the past three months, is an attest of this requirement.

The capacity of the electric locomotive. The capacity of the electric locomotives was based upon their ability to handle a trailing load of 200 tons in local service with stops averaging those that exist between stations between New York and New Haven. As a matter of fact, the station stops between Stamford and New York average very much greater than between New Haven and New York, and as very quick turns are made

TABLE X.

TRAILING LOADS IN EXCESS OF LOCOMOTIVE GUARANTEES.

Date	Service	Train No.	Locomotive No.	Trailing train weight	Percentage over weight
10/18	S. Ex.	59	07–024	538	7.6
	S. Ex.	18	04–09	623	24.8
	S. Ex.	1	038–041	604	20.8
	S. Ex.	2	04–027	682	36.4
10/19	S. Ex.	21	038	284	13.6
	S. Ex.	15	028	327	30.8
	S. Ex.	45	040–041	561	12.8
	S. Loc.	215	08	236	18.0
	S. Ex.	63	030	302	20.8
	P. G. Loc.	181	041	348	39.2
	S. Ex.	269	034	277	10.8
	S. Ex.	1	06–036	674	34.8
	S. Ex.	29	01	280	12.0
	S. Ex.	2	04–09	609	22.0
10/20	S. Ex.	2	03–08	762	52.0
	S. Ex.	1	030–033	684	36.8
	P. C. Loc.	181	040	314	25.6
	N. R. Loc.	151	023	344	14.7
	S. Loc.	252	020	235	17.5
	S. Ex.	11	07–024	560	12.0
	S. Ex.	15	013	400	60.0
	S. L. Ex.	260	034	273	9.2
10/21	S. Ex.	21	07	331	32.3
	S. Loc.	287	04	223	11.5
	S. L. Ex.	260	03	271	8.4
	S. L. Ex.	246	038	283	13.4
	S. Ex.	15	040	332	32.7
	S. Loc.	216	026	256	28.0
	S. Loc.	252	033	275	37.5
	S. Loc.	206	038	257	28.5
	N. R. Loc.	151	010	338	12.7
	S. Loc.	207	025	262	31.0
	P. C. Loc.	181	09	297	18.8
	S. Ex.	1	032–037	698	39.5
	S. Ex.	29	010	280	12.0
	S. Ex.	2	07–032	817	63.6
10/22	S. Ex.	21	010	328	31.2
	S. Ex.	55	040	317	26.7
	S. Loc.	287	026	226	13.0
	S. L. Ex.	260	02	285	14.0
	S. L. Ex.	246	016	274	9.6
	S. Ex.	245	037	279	11.6
	S. Ex.	15	034	391	16.4
	S. Loc.	252	034	281	40.5
	S. Loc.	222	011	222	11.0
	S. Loc.	206	037	251	25.5
	N. R. Loc.	151	030	343	14.3
	P. C. Loc.	181	033	302	20.8
	S. Ex.	1	06–038	668	33.6
	S. Ex.	29	028	271	8.4
	S. Ex.	2	06–038	700	40.0

Date	Service	Train No.	Locomotive No.	Trailing train weight	Percentage over weight
10/23	S. Ex.	21	013	339	35.6
	S. Ex.	55	012	320	28.0
	S. L. Ex.	246	02	263	5.2
	S. Ex.	15	010	377	50.8
	S. Ex.	11	05–08	542	8.4
	S. Ex.	56	024	313	25.2
	S. Loc.	252	027	269	34.5
	S. Loc.	215	09	241	20.5
	S. Loc.	206	02	233	16.5
	S. Loc.	207	03	245	22.5
	P. C. Loc.	181	028	318	27.2
	S. Ex.	1	017–041	747	9.6
	S. Ex.	2	03–011	853	70.4
10/24	P. C. Loc.	190	012	281	12.4
	S. L. Ex.	292	010	258	3.2
	S. Ex.	15	019	333	33.2
	S. Ex.	24	06	396	58.4
	S. L. Ex.	288	02	258	3.2
	P. C. Loc.	176	022	298	19.2
	P. C. Loc.	172	037	290	16.0
	S. Loc.	212	041	245	32.5
	N. R. Loc.	151	029	323	7.7
	S. Loc.	207	06	246	23.0
	P. C. Loc.	181	033	299	19.6
	S. Ex.	1	019–036	624	24.8
	S. Ex.	29	08	271	8.4
	S. Ex.	2	026–030	819	63.9

at both termini, the service may be said to be more severe under these conditions than under the guaranteed conditions of purchase. It is interesting to note in Table X the trailing loads, taken at random, hauled by the New Haven electric locomotives for the week ending October 24, 1908.

Comparative steam and electric engine mileage. September 5, last, Labor Day, offered an interesting day to note what mileages could be made by the electric locomotives. Table IX gives an individual record for each of the 38 electric locomotives in service that day.

In obtaining an average for all electric locomotives of 212 miles, it is to be remembered that this was made for all classes of service, express, express-local, and local, and further that the mileages were made over three short terminal runs; namely, Stamford, Port Chester, and New Rochelle to New York, the distances being approximately 34, 26, and 17 miles, respectively. As indicated in the table, several engines made eight runs, two of them nine, and one ten. It is difficult to get an exact comparison for steam locomotive-mileages. All of the electric engines are confined to one division, while the steam locomotives do interdivision service. However, using the records of the 1906 steam service for Labor Day and considering steam locomotives doing mileage in and out of the present electric zone, out of 117 locomotives the following record is to be noted:

10 made over 300 miles.
20 " between 200 and 300 miles
21 " " 150 and 200 "
34 " " 100 and 150 "
32 " under 100 miles.
117

Thus with division limits double that of the present electric division, and with the additional advantage of interdivision runs, the electric mileage for this concrete case averaged 34 per cent. better than the steam mileage.

The Electrification in Its Relation to Matters Other Than Traction

Telegraph and telephone. Single-phase electrification affects telegraph and telephone systems whose wires lie parallel with and in close proximity to the railroad. The corrective for this disturbance has proved to be simple and not costly. Briefly described, it consists of compensating transformers whose secondaries are a part of the telegraph and telephone wires and whose primaries receive their voltage from pilot wires strung on the same cross-arms as those bearing the telegraph and telephone wires, and thus having impressed upon them the same voltage, by electromagnetic induction, as the telegraph and telephone wires. The transformer secondary voltage is approximately equal and opposite to the induced voltage on the telegraph and telephone wires and thus constantly compensates for it throughout all ranges of induction due to the single-phase wires.

An interesting commentary on the efficacy of the compensating transformer is that its use obviated the necessity of any change in the physical location of the telegraph and telephone lines within the zone of induction, and has thus been the means of removing what at first was rightly considered a very offensive attribute of the single-phase system.

Public safety. As no fatality to the traveling public has happened by reason of the high-voltage wires since the system has been in operation, this would indicate the safety involved in its construction. The catenary form of construction as applied to the suspension of the trolley wire virtually eliminates all danger of these wires falling. On the other hand, the feeder or by-pass wires are not suspended by messengers, and although the 300-ft. spans used in this construction are not uncommon, it has been considered a wiser policy to reinforce all such spans which are above passenger platform stations. It may be of interest to state also that the scheme of reinforcement is not to cradle or place supplementary wires in connection with this span, but simply use a steel wire with a large factor of safety reinforced by copper for conductivity conductor and supported from the struts by insulators. The resistance to ground of this construction will be far in excess of the ordinary insulator used in the open construction with the steel wire connected to it in such a manner as to make impossible the burning of this wire in two in the case of the insulator breaking down.

Foreign wires. All electrifications are subject to foreign wire crossings. As in the case of suspension of high-voltage wires over passenger platforms, instead of using supplementary catenaries or cradles, the safer (and incidentally the cheaper) method of crossing is to use at the crossing heavier (and possibly guyed) poles, better insulation, and larger wires than are commercially necessary in the other parts of the foreign transmission line. High factors of safety with economy are obtained following this policy.

COMMENTARY

Lightning protection. An ideal arrangement of catenary construction in relation to lightning protection would be to have the overhead messenger system grounded, and from it suspended by insulators a secondary catenary system, to which in turn would be attached the contact wires. Even in the New Haven case, where the overhead messenger system is not grounded, lightning has given but slight trouble. This is probably due to the very great number of grounded steel trusses and struts projecting above the electrified wires. Lightning was the indirect cause of one of our delays, but played only a small part in the real cause which can be attributed to the surge of current occurring at the time lightning caused a ground. At that

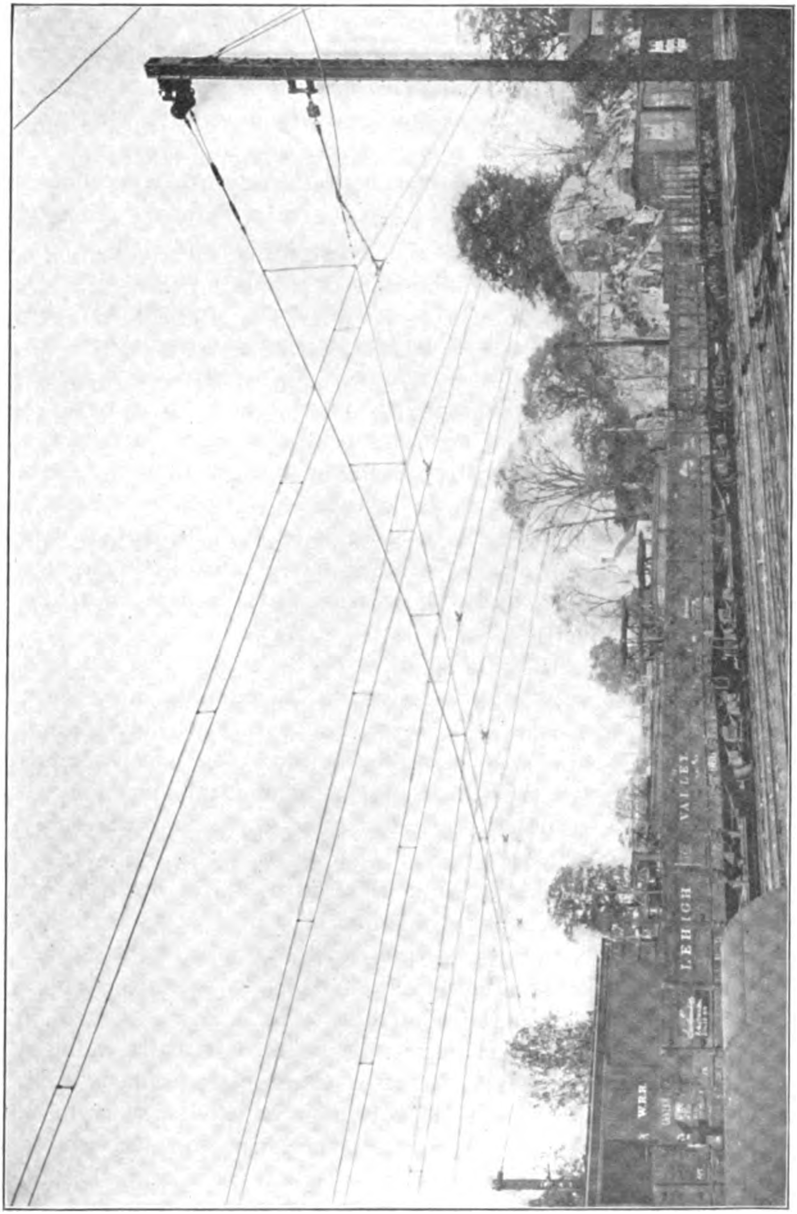


Fig. 13—Cross-catenary construction East Portchester yard.

time the feeders had not been rearranged, nor had the impedance coils been installed in the power-house circuits. On the occasion of this ground, due to the lightning, we lost several of the anchor bridge circuit-breakers; this naturally tied up the distributing system, preventing the proper restoration of voltage to the trolley wires. The conditions are now such that the circuit-breakers will relieve short-circuits due to this cause.

Grounds. Structures supporting high-voltage insulators should be grounded. Particularly is this true of structures foreign to the railroad company, such as highway bridges. This arrangement insures a prompt response of the circuit-breaker apparatus, and carries out the good practice universally applicable, that the material supporting the insulator be grounded. This principle has application in wood-car construction. Positive grounds between Pintsch gas pipes and both car trucks should be made to avoid any arcs being drawn under the car body. On two occasions the gas in the Pintsch mains of New Haven cars has been set on fire on account of connection with electrified wires. While the percentage is low, being two cars in about 400,000 during the period involved, with little damage in either case, and that to the cars, it is a matter not to be ignored.

Many of our catenary bridges, of both the intermediate and anchor type, serve to support signals. Signal men have been entirely free from coming in contact with the high-tension wires, by the simple provision of grounded close mesh screens interposed between the signal platforms and the high-voltage wires. The value of two grounds can be rated considerably higher than twice that of one.

Tell-tales. Tell-tales in connection with an overhead system offer a peculiarly difficult problem. It is quite apparent that the pantagraph current collecting device would get into either electrical or mechanical difficulties with the present form of tell-tales. We have experimented at some length in trying to produce an electrical horn that would be automatically sounded by an approaching train. There is nothing particularly difficult in getting the automatic action or in producing a noise. The superiority of the tell-tale over the horn, however, is that no matter how much noise the freight train is making, the tell-tale always notifies, while in the case of the horn should the freight train be making more noise than it, the notification is lost. A horn if used for this service should be a large one.

As a matter of fact, the necessity of tell-tales is a bit of a relic of the barbaric past. In the days of hand brakes, the brakeman had to walk the roofs of cars, and low bridge warnings were necessary. To-day the braking is all done from the engine cab, except in yards where, of course, the overhead wires have their normal height of 22 ft. from the rails, permitting safe clearances for manual operation of the brakes.

Train lighting and heating. On account of the necessity of wiring for electric heating and lighting some 2500 coaches, it seems reasonable to retain the present method and apparatus of heating and lighting the trains in the electric zone. To accomplish this it was only necessary to supply each electric locomotive with a small steam boiler used solely for train heating. The Pintsch gas system has been retained intact. Later, when the service is sufficiently extensive, all trains will be heated and lighted by electricity.

All multiple-unit cars are to be heated and lighted by electricity. The problems of heating and lighting a multiple-unit train and a locomotive train are quite different. In the former the current is fed into the train at several points, as many as there are motor cars; in the latter it can be taken only from the locomotive (if there are two locomotive units, of course, it can be supplied from both). Again, in the case of the multiple-unit equipment, the supply of current is along progressive points of the train-length, thereby not requiring train bus-bars of excessive copper section, while in the case of the locomotive train, the supply, whether from one or two units, will be at the head end of the train, thus requiring a transmission of considerable length. A train of 12 cars, for instance, would be between 700 and 800 ft. long. Allowing 24 kw., maximum, for heat and light per car, would require the delivery of about 300 kw. apparent power. An investigation of this department in electrification has brought out some interesting details, particularly in reference to locomotive transformer design and electric car jumpers.

Fatalities. As has been pointed out, we have had several fatal accidents, due to men coming in contact with electrified wires. We are none the less concerned that in every instance they were men employed by the company. In each instance the accident was due to carelessness or violation of instructions, and most of the accidents occurred during the period of construction. The operating period has provided a less number of these unfortunate events, and the records to-day now seem to indicate that the future will be free from this most regrettable feature.

Cross-catenary versus bridge-bents. The excellent results of a year's experience with cross-catenary construction in our Port Chester yard, Fig. 13 where as many as ten tracks are spanned, is tempting encouragement for its application to main-line work. Should the cross-catenary be used, anchor bridges should be spaced at close intervals, say one per mile. The question of the use of cross-catenary versus the bridge-bent on multitrack roads, however, depends largely upon the right-of-way conditions. Cross-catenary struts have to be guyed. In many instances right-of-way limits will require the guy to be placed on foreign land. If the additional cost of the foreign land brings the catenary bent up to or more than the cost of the bridge-bent it loses its object.

Single- versus double-catenary construction. Lack of operating data led the engineers of the New Haven road to take no chances with the overhead construction, and the double catenary was considered the safest. The adoption of single, double, and compound systems of catenary suspension is so intimately and definitely related to the number of tracks, the length of longitudinal spans, and the cost of transverse supporting structures and foundations, that the determining of the most economical type of catenary construction must necessarily include the consideration of these factors, and for this reason simple standardization adapted to all conditions is impossible.

Single-phase operation. The New Haven system provides that the volt manufactured in and leaving the doors of the power house, is the same physical volt that knocks at the doors of the locomotives. Thus the line is the single link that unites the power house and the locomotives. All such adjuncts as step-down transformers, synchronous converters, storage-batteries, and low-voltage distributing systems with their necessary attendant complement of help is dispensed with. The Cos Cob power house has the usual number of men for a station of its output, and the locomotives are operated by the electric locomotive engineer with the customary assistant present for emergency. This crew holds good for single- or double-unit trains. An emergency repair train is the guardian of the line, attending to all matters pertaining to its repair and maintenance. Including the night and day crews of the emergency train, the number of men employed to maintain the distribution system is nineteen. This covers about 100 miles of single track, including yards.

Conclusion. The writer will not use the conventional method of summing up and making recommendations. The paper has been written with the intent to lay before the members of the American Institute of Electrical Engineers a practical picture of the New Haven single-phase electrification, describing the first suit of clothes it wore and what it is wearing now. He is conscious of the innumerable little points of real interest that time and opportunity have not permitted him to insert here, but he trusts to the discussion to bring them out. The description of the faults and how they were handled will answer for the usual column of recommendations. In concluding, an interesting definition of engineering comes to mind; namely,

> Engineering is the art of making a dollar earn the greatest interest.

The writer has intentionally omitted the discussion of the operating costs of a direct current versus an alternating current system; but, bearing in mind the preceding definition, it is his belief that in the electrification of steam roads to-day straight alternating current traction is the agency through which that title can be earned.

History sustains the undeniable truth that alternating current is the preferred agent for the transfer of electricity where either distance or capacity is involved. A railroad involves both. Granted, therefore, that the alternating-current traction apparatus has received the trade mark of practicability, what further argument does it need in its favor?

In connection with the New Haven electrification I wish to speak of the privilege of association with Mr. E. H. McHenry and Mr. Calvert Townley. Upon Mr. Townley devolved the responsibility of decision as to the form of electrification selected. Neither the object nor the scope of this paper can include a description of the analytical course of procedure preparatory to the conclusion that the New Haven road would adopt the single-phase form of electrification. Suffice it to say that Mr. Townley's conviction to accept this responsibility were sufficiently strong to lay the foundation of this work. To Mr. E. H. McHenry, whose serious illness had prevented his filling the office of vice-president in charge of matters pertaining to engineering, fell upon acession to that office, the responsibility of ratification or disagreement with the policy as set forth by Mr. Townley. That ratification is better written in the details of the electric zone itself, as in each department of power house line and locomotive may be seen the betterments due to his suggestion. To him is due the credit of the practical issue of this electrification.

This paper would indeed be incomplete did I not refer to the splendid courage and indomitable pluck of our contractors, who through a fire of criticism and business depression perseveringly stuck to their belief in the principles they were advocating. They can now have the satisfaction of viewing something begun and something finished; for while there may be many improvements to accrue to the alternating-current, single-phase system, the trunk-line principles have by them been laid and demonstrated.

DISCUSSION ON "HIGH-VOLTAGE EXPERIMENTS AT NIAGARA." ATLANTIC CITY, N. J., JUNE 30, 1908

(Subject to final revision for the Transactions.)

Henry L. Doherty: This paper is a most valuable contribution to a subject of great importance. I will not attempt to discuss any of the details of the paper for fear it will distract from the broader matters which are worthy of consideration.

As a preface to my remarks I want to say, first, that the American Institute of Electrical Engineers is now a body of great importance, and it is in a position to exercise a pronounced influence upon the educational, industrial and commercial progress of this country; and second, that few, if any, other organizations can boast of greater aggregate intelligence or influence than can this organization. Its members are in touch with nearly every class of people, and their individual work and opinions are universally respected.

This paper deals with the researches made to secure a greater knowledge of the problems which underlie the methods for transmitting electrical energy.

Had my time permitted, I would have offered to this Institute a paper at a much earlier date, covering the various methods for the transportation of energy in its various forms, and would have attempted to show the relative cost of transporting energy, or its material, by various means, such as: (a) electrical energy by transmission at high voltage; (b) natural gas by means of pipe-lines; (c) coal and oil by rail; (d) oil by means of pipe-lines; (e) steam and hot water by means of pipe-lines.

I think it can readily be demonstrated that, where a good load factor exists, transportation of energy can be secured at the lowest possible cost by means of electric transmission.

We often find ourselves, as engineers, greatly handicapped by the sentiment prevailing amongst bankers and investors to whom we must look for the necessary funds to finance our undertakings. Often the method of presentation will do much to influence, favorably, prejudiced investors capable of furnishing funds for the enterprise.

It was my intention to show that these so-called "long-distance transmissions" constituted a problem in transportation which could be reduced to the same terms as railroad statistics—which are always available—and their commercial efficiency measured by a comparison therewith. It was my belief that such a comparison would put this whole field of work on a more substantial basis in the minds of the public and increase the activity in this line of work, thus greatly increasing our usefulness.

As my own time will not permit, and as there are many men in the Institute who can do this work much better, I am taking the liberty of suggesting this comparison in relation to the consideration of this subject.

I believe the engineer, and the engineering organization, have been undergoing an evolution which will materially change their scope of usefulness. The engineer must now know, with more or less intimacy, other lines of business; and, as an example, he must know more or less of financial methods and possibilities. He must often interject his engineering methods into other lines of work—in fact, it is remarkable how many of our general business matters are capable of solution by engineering methods and engineering laws. He must know how to state his conclusions in such form as to give readily a clear and correct impression to men educated in other lines of work. The engineering society must not only know the needs of its own members, but must know how to influence other classes of people for the benefit of its own class.

The recent conference called by President Roosevelt for the conservation of our natural resources was, to my mind, a great stroke of statesmanship; and, using this occurrence as an illustration of my preceding statement, it seems to me that as the members of the Institute represent an immense sum of knowledge on this problem—which we all recognize is a matter of national importance—it would not be impertinent for the organization to undertake to contribute materially to the solution of this problem and to make all parties in interest know that it is in a position to do so, and that it should be considered as an important factor in this work. It is hard for me to refrain in any discussion from applauding the excellent work done by this Institute in recent years; and I avail myself of every opportunity to urge that it do still more, and still further widen its field.

Regardless of the other contributions made by Mr. Mershon I want to point out particularly that he has demonstrated that it is possible to secure financial support for practical research work of this character. This demonstration may prove of greater value to the future achievements of the Institute than any specific work heretofore presented to it. I strongly urge that the Institute should place on record, in unmistakable terms, its appreciation of the generosity of these men, and that at this meeting an effort be made to point out to everybody that such contributions cannot help but prove, if properly directed, great factors in our industrial progress and great factors in the commercial prosperity of this country as a whole.

While many may believe that an organization of this sort should attempt to exert influence only over its own members, here is an excellent example of how it may exert influence over men of great wealth, who are willing to contribute liberally to our research work if it promises benefits to the industrial progress of the country. It seems to me not hard to point out the great value of such contributions.

Elihu Thomson: Mr. Mershon some time ago told me of some of his results, and asked me if I could make any suggestions as to the cause, that is, as to the actual thing happening; if I could suggest some physical conception. Before I make any attempt at this—and it can only be an attempt—I should say that there is true gratification felt in finding that funds can be at times available, and may in the future be more frequently available for engineering research as distinguished from pure scientific research. Yet the results of the paper while quite practical, as applied to transmission lines, have, further, germs of scientific progress in them—progress along the lines of pure science.

I will not take the time to discuss in detail the various matters of the paper. Perhaps it would be well to turn to the last pages and take up the final conclusions, and note, if we can, whether the results appear to be rational or not. The " critical point " is well understood; and I do not see, in reading over Conclusion 1, that there is anything to be said further; there is a certain voltage called the " critical point " at which a very appreciable loss begins, and that point is coincident with the visual manifestations, corona, or decomposition, or static breakdown, of the dielectric surrounding the conductor.

Conclusion 2 reads, " That there may or may not be an appreciable loss existing below this critical point, depending upon the atmospheric conditions." It seems to be a remarkable result, where no visible effect can be found around the conductor, that there is still even with air in a dry condition, a notable loss.

Conclusion 3 reads, " That the presence of floating particles in the atmosphere may produce a loss below the critical point (Ryan)." That, I think, we can readily understand; the particles may be attracted to the conductor, and may be the means of causing a diffusion of energy—they may be pulled, as it were, towards the conductor, breaking down the homogeneity of the dielectric and thus causing a loss of energy.

Then, again, we read in Conclusion 4, "That the presence of moisture in the atmosphere may produce a loss below the critical point." Here we find that Mr. Mershon has given us conditions under which the moisture produces a loss depending apparently on the amount of water present in a given volume, that is, on the absolute vapor pressure of the water and the condition of the water as to its being more or less near condensation, or whether it is further from the condition of condensation or nearer to it. This leads us, I think, to the consideration of the fact that water vapor just above its vaporization point cannot be considered as a true gas. It has to be heated considerably beyond its vaporization point to become a true gas. In a gas, according to the kinetic theory, the molecules are flying about and colliding in all directions; they have a certain velocity, but the velocity is not uniform, some molecules being accelerated beyond the mean velocity and others very definitely retarded below the mean velocity. Now, when a liquid is near condensation, some of these molecules may be robbed almost entirely of velocity, but we know that if this occurs in a vapor, such as water vapor, such molecules may be considered as for a very brief time in the liquid state. Afterwards they are again separated by colliding with other molecules at higher velocities. In other words, in this instance there is an unstable condition in the gaseous substance, and the nearer therefore to condensation, or the greater the humidity—relative humidity—the more this factor will come in; the state of some small fraction of the water vapor being changed from that of a gas to a liquid. A larger number of molecules are then in a state of quiescence, for the time being, or in the state of water for a very short interval, the nearer the approach to condensation. This condition would explain why the vapor product—if our theory is correct—is concerned. According to the result obtained by Mr. Mershon the vapor product must be taken; not only the amount of vapor water present, but the state of that water. The number of molecules of water vapor so condensed, as water—or so losing their velocity and becoming for the time being, only instantaneously, more or less liquid—would be greater with the greater amount of water, as expressed by the greater vapor tension of the water, and greater also the nearer to the point of condensation, or the greater the humidity. We must infer from this, however, that the molecules of water in the quiescent condition have some unusual power of absorbing energy; that they can receive energy, can be accelerated or can be decomposed or driven apart by absorbing energy from the conductor. This action might go on invisibly, it might simply be that the water is, as it were, electrically evaporated or put back into its high-velocity condition by energy expended. This view is merely put forward as a suggestion, depending on the validity of our ideas of the action of molecules of gas; bringing together Conclusions 3 and 4, " That the presence of floating particles in the atmosphere may produce a loss below the critical point " and " that the presence of moisture in the atmosphere may produce a loss below the critical point."

Conclusion 5 is as follows: " That the presence of moisture in the atmosphere affects the loss both above and below the critical point." I think this would naturally follow from the other idea, that the more water the more loss would occur, even above the critical point; that the particles would be in condition to carry away more energy, on the assumption that water particles have an exceptional capacity in that direction.

Conclusion 6 is as follows: " That the presence of moisture or floating particles in the atmosphere affects the position of the critical point." This, again, means that the water particles, or the moisture particles, would act as a sort of intermediary in extending the influence around the conductor, and accentuating the production of the critical point; or in other words, the water would be more readily ionized than dry air, and become the medium for the absorption of larger amounts of energy, causing dielectric breakdown.

Conclusion 7 reads: "That the critical point corresponds to a partial breakdown of the dielectric." That, of course, we can readily assume.

Conclusion 8: "That the critical point coincides with the voltage at which luminosity or hissing (or both) of the conductors begins." Either the sound or the luminosity may be an index of the breakdown—actual sparking into the dielectric, and a reversal of current flowing through a short distance with each alternation, and naturally this would be equivalent to a high-resistance leak around the conductor, causing loss.

Conclusions 9, 10, and 11 are as follows:

9. "That the critical point depends upon the maximum value of the electromotive-force wave and the distance between the conductors.

10. "That the critical point depends upon the local rate of fall of potential or dielectric stress at some point in the atmosphere and, therefore, depends not only upon the maximum value of the electromotive-force wave and the distance between the conductors, but also upon the diameter of the conductors (Ryan).

11. "That there is a loss over insulators which is affected by the moisture conditions of the atmosphere."

I do not think there is much necessity for my commenting upon these conclusions. They seem to be the natural results to be expected and are fairly well known.

Conclusion 12 reads: "That the variation of the atmospheric loss between conductors, the variation of the loss over insulators, and the variation of the critical point due to the moisture conditions of the atmosphere bear to the vapor product (*i.e.*, the product obtained by multiplying the vapor pressure by the relative humidity) a definite relation which, so far as it is at present known, is an empirical one." In that conclusion we come to the particularly novel point, namely, that we must have not merely the amount of moisture, not merely the saturation, but we must multiply together the amount of moisture present, or the amount of water vapor by its state or condition, so to speak, which I have above suggested as that of more or less imperfect gas.

Conclusion 13 reads: "That the loss over insulators in a fog is very much higher than the loss in dry air, and somewhat higher than that in a heavy rain." This can be easily understood. If the whole insulator was covered with water, the conduction over the upper surface of the insulator would undoubtedly be greater than if it were covered with fine particles of water. Its upper surface would be, in other words, of lower resistance and therefore cause less loss than if the fog settled upon the surface and made it a very high-resistance surface.

Conclusion 14 reads: "That the smoother the surface of the conductor, the less the loss and the higher the critical point." We would be naturally ready to admit this, on account of the absence of projections or points; but 15, which reads: "That the stranding of the line conductors reduces the loss and raises the critical point due to the increase of the equivalent diameter of the conductor," seems to be inconsistent therewith. With the stranding of the line conductor we would reach a limit, of course, very soon. The continued finer and finer stranding would not give a continued increase in real diameter, as the spaces between the wires of large or small gauge are relatively the same, so that we seem to be, in Conclusion 15, roughening the conductor and reducing the loss thereby. Conclusion 16 reads: "That the increase of the equivalent diameter of the conductor is greater the greater the number of strands." Here we have roughened still more by making the strands fine and thus have a large number of spiral projections or ridges all over it, and yet the increase of equivalent diameter is greater; whereas under Conclusion 14 it is said that the smoother the surface of the conductor, the less the loss and the higher the critical point. These things seem to need further investigation and some explanation, because they do not seem to be consistent. One can imagine that the stranding could go on until the conductor was covered with extremely fine ridges, and then we should consider it as possessing a rough surface; not an irregular roughness, but ridges nevertheless.

Conclusion 17 reads: "That the weathering of conductors (or at any rate the aluminum conductors and probably copper ones also) does not appreciably increase the loss or lower the critical point." I do not know that we should expect to find any great difference between conductors of aluminum or copper, as referred to in this Conclusion, or that a slight film of oxide would have any particular effect on the losses.

Conclusions 18 and 19 are as follows:

18. "That the loss and critical point are the safne for copper and aluminum under the same conditions."

19. "That anything which increases the charging current of the insulator increases the loss over the insulator."

I think this we could admit. If the insulator dielectric were free from all dielectric hysteresis, then, of course, we should not expect Conclusion 19 to hold, but with ordinary materials it would undoubtedly be true that the loss would increase with the increase of the charging current. It would hence follow that if we interpose layers of air between the insulator pin and the wire or conductor, and these layers of air have the total effect of reducing the charging current very considerably, we may save some loss from the insulator. On the other hand, if we introduce only thin or moderately thick layers of air which have to be worked across by blue discharges, or anything of that sort, then of course we increase the loss by dividing the insulation. This comes directly in line with Conclusion 20, which reads, " That the loss over an insulator on a wooden pin is greater than that over an insulator on a metal pin, because the resistance of the wooden pin is in series with the charging current of the insulator," and would point to the fact that if we use a metal pin and want to avoid the losses as much as possible, we should make the metal pin fit the insulator very closely by some sort of conducting filling, and not have any space to be worked over by discharges from the pin to the inside surface of the insulator; but that is probably not of very great consequence.

Conclusion 21 reads: " That the atmospheric loss between conductors and the loss over insulators decreases with the frequency. The law of the decrease is not at present accurately known." I think this might naturally be expected, as the greater frequency would stress the dielectric more times per second, although a single long wave would no doubt give more loss than the shorter wave of equal amplitude.

Conclusion 22 reads: " That neither the critical point nor the loss between cables is affected by variation in the distance of the cables from the ground." I suppose this follows, because in ordinary cases the cables are at such distances from the ground that there is none of the effect of incipient brush discharge and increase of loss, such as we have when the conductors themselves are near together.

I have to say in regard to the paper, that it is certainly a very interesting and valuable one, and points the way to further useful investigation.

Samuel Sheldon: Prof. Barus, at Brown University, and members of his department, have carried on very extensive investigations as to the conditions of the atmosphere in the vicinity of Brown University, in Providence, and also on Block Island, which is pretty well out to sea, with the result that he finds ions always present in the atmosphere at both places. Now, these ions each have upon them a definite charge of electricity although they are of various shapes and conditions. If one of these ions be placed in an electrostatic field of a given intensity, a force is exerted upon it which is equal to the product of the charge times the strength of the field. Townsend has determined that under a given set of conditions a very definite and measured amount of energy is necessary to produce by impact ionization of un-ionized or non-ionized particles.

Now, under given atmospheric conditions there is an average free path between the particles that may come into collision; and if the collision represents a sufficient amount of energy, ionization of the particle that is struck will take place. The fact that energy is equal to half the mass times the square of the velocity, and that the velocity squared is twice the acceleration times the distance through which the particle moves, taken in conjunction with the fact that with the same force the acceleration is inversely as the mass, shows that irrespective of the size of the particles, if the latter move over the same distances, under the same force, they will arrive at the end of these distances with the same energy. If, therefore, they come into impact and the field has been sufficiently strong, ionization will take place. There will result more ions than were present before, and these again will set up further ionization, and therefore, ionization will spread like a disease in a field of sufficient intensity, until there are a sufficient number of ions to carry a discharge by convection. This explains many of the results which Mr. Mershon has obtained.

Henry Floy: While the Institute is certainly to be felicitated on being the medium through which the valuable data collected by Mr. Mershon is to be transmitted to the engineering world, and while Mr. Mershon is to be congratulated most heartily at the happy outcome of this long and tedious experimentation there is another fact brought out by this paper which is particularly interesting to me, one which Mr. Mershon and Mr. Doherty have already touched on, and that is the disinterested generosity of Mr. J. E. Aldred, Mr. Frederic Nicholls, Mr. James Ross, and Mr. George Westinghouse. It seems to me that the engineer has now reached a point, at which I have long hoped he would arrive, where in the minds of commercial business men he is no longer considered only a theorist and scientist. And so we now have a most encouraging example of practical business men entrusting, in an unrestricted manner, their funds to a scientist for carrying on an investigation in his own way. The precedent thereby established seems to me to mark an era in the engineering world. If we can only encourage men of financial ability to subscribe funds to those engineers who are as capable as Mr. Mershon is to originate and carry out a series of tests and experiments, we have gone a long way in advance of previous achievement.

The character of the results and conclusions of Mr. Mershon are surprisingly large to any one who has attempted to carry on a set of experiments of this character, particularly when it is realized that any one of an innumerable number of accidents might have vitiated the entire results.

With regard to the deductions made by Mr. Mershon, perhaps the most disquieting in the whole paper is the one shown, for example, by the curves in Fig. 43, showing the relation between the critical point as determined by his experiments and those of Professor Ryan. Mr. Mershon has noted that his critical voltages are about sixty per cent. of Professor Ryan's results. This difference seems to me most extraordinary, and as far as I know Mr. Mershon has not offered any explanation of it. I had hoped we would hear from Professor Ryan with regard to this matter. It is possible that part of the difference may be accounted for by the failure of Professor Ryan to have accurately determined the points of luminosity. As I understand his experiments, his critical points were determined mainly by visual observation, and if he did not fix the points exactly owing to personal equation or to failure to carry on his experiments in a room absolutely devoid of light, his voltages would be higher than Mr. Mershon's, who determines his values by a continuation of the lower curve. This difference in method, however, would not, apparently, wholly account for the great difference in the voltages at the critical points. While I am unable to criticize Mr. Mershon's method, it would seem as if his voltages were somewhat low. Turning to Fig. 43 and assuming the vapor product of 0.4, and the diameter of the conductor as one-quarter inch, we find that the critical point in kilovolts is 75. From what I have heard of the line at Grand Rapids, Michigan, where they are operating at 75,000 volts, and at other very high-tension installations, luminosity does not appear on those lines. It may be that the conductors are more widely separated or of different diameter, or that the vapor product is not as given in this table; but it would seem as if in the course of their operation there would be some fluctuation in the voltage or variation in conditions so that luminosity would be observable. Under the conditions stated by Mr. Mershon, luminosity should appear at 75.000 volts.

It would seem as if further investigation, perhaps by some other or outside party, should be carried on to determine whether Mr. Mershon's results can be absolutely relied upon, or whether the figures previously given by Professor Ryan are nearer correct. It would be unnecessary to repeat the experiment throughout, but simply to check a few points on certain curves. The location of the critical.point is certainly a very vital question with engineers who are designing high-tension lines.

The announcement by Mr. Mershon of the less resistance of wooden pins, as compared with iron pins, is certainly astonishing to most of us, but in view of his measurements, and the explanation given, we must acknowledge it as a fact.

In regard to the insulators, Mr. Mershon apparently tested no suspension-type insulators. Of course, tests of these insulators would have been especially interesting at this time, as they are coming more and more into use. Although he does not say so, his statement indicates he has learned the ideal form of insulator for a given voltage. Perhaps, in another paper, he will give us an idea as to the form of the insulator, and the number of petticoats which this ideal form of insulator should have, for a given voltage.

Chas. P. Steinmetz: Mr. Mershon has given us a very valuable paper, increasing our knowledge of what takes place in conductors when they reach such high voltages that the air surrounding them ceases to be insulating, begins to break down.

He has proved again the law given some years ago, and illustrated in his paper, that the voltage loss is a curve of two branches one at lower voltage, of very small loss, and the second branch at high voltage, rising very rapidly. There is one point, however, concerning which I cannot agree with him, and that is the method of determining the critical point as the point where deviation begins from the lower branch, as seen in Fig. 38. I do not think that is the correct critical point. We must expect that the conductor and surrounding conditions are not absolutely uniform, and that the transition from one condition to another one can only be gradual. The first beginning of a brush discharge at some isolated point, some kink in the conductor, cannot be considered as the voltage where the breakdown strength of the system has been reached all over the conductor, and I believe this feature may account for the discrepancy between Professor Ryan's and Mr Mershon's results. I also agree that it would not be proper to take as the critical point the point where the upper or higher curve is perfect. Theoretically if we had the equations of the lower curve in Fig. 38, and of the upper curve, the point of intersection would be the proper critical point. This would be at higher voltage than that assumed by Mr. Mershon. We obviously cannot do this, as we do not have the equations of the two curves; and by estimating it, by continuing such curves, it is very difficult to get anywhere near accurate results, that is, results from which you can derive numerical values of the breakdown strength of air.

I should therefore suggest a slight modification of the method, which may give accurate results or may not. It is to plot the curve in Fig. 38 with the logarithm of the ordinate against the logarithm of the abscissa. Both branches of the curve may theoretically be expected to go through the origin, and such curves going through the origin, can frequently, at least within a limited range, be expressed by some power of the abscissas, that is, by a curve of the equation: $y = A x^n$. If you now plot logarithm y against logarithm x, you get a straight line. If in Fig. 38 you were to plot the logarithm of the ordinate against the logarithm of the abscissa, you may get two straight lines, one extending up to 70,000 volts, and the other extending from 80,000 volts upwards, connected with each other by a curved branch; and where you have straight lines, at least for some distance, it is very easy to extend them and so get the point of intersection very sharply, which gives the critical value with much greater accuracy than it can be derived by extrapolation from the original curve. It all depends on the character of the two curves, whether they will give straight lines in the logarithmic representation or not, but it is quite likely they may do so, or at least the deviation from the straight line will be small, and therefore this method should be tried.

While the results, as derived here, are extremely valuable in showing the existence of the critical value, we really want to have more than that. We would like to get the exact numerical value of that critical voltage, and compare it with the conductor diameter, and from that calculate the potential gradient at the conductor surface, and compare it under different conditions; and also compare it with that derived from the striking distances with needle points, where you get the analogous effect. After determining numerically the breakdown strength of air, or its breakdown gradient, very many of these features could be predetermined theoretically and pre-calculated. For this work, very interesting and valuable data are afforded by this paper. We all agree that the future of power transmission depends on going to higher and higher voltage, and you see that the loss of power from the line increases enormously with the increase of voltage beyond the critical point, and so would limit the permissible transmission voltage. Now, if we know how this loss depends on conditions of conductor surface, conductor diameter, etc., it would be a question of engineering design how to lay out the conductors of the transmission line, so as to be able to use as high voltage as possible, and still have a negligible static loss into space.

Percy H. Thomas: There are two broad aspects from which this paper may be viewed: first, that of commercial transmission work; secondly, that of the scientist. In the first aspect, what we need to know is whether this loss from conductor to air is going to actually limit the development of power transmission. I think we can say, pretty conclusively, from Mr. Mershon's results, that for the immediate future, at any rate, these losses are commercially practically negligible. The experiments have been so carefully made and their results so carefully stated, that unless some very extreme conditions arise, they will not have to be done over.

In regard to the scientific aspect of the paper, there are a number of comments which I would like to make.

I was very much interested in Dr. Thomson's explanation as to the cause or the physical meaning of the relation between loss and vapor product. Personally, I had not been able to find any consistent hypothesis. His explanation seems to be very reasonable. I ask him if his conception as to the manner in which the molecules or minute particles of water act is as convectors of electricity?

Elihu Thomson: They absorb energy by being separated, again by re-evaporation. The mere addition of energy to a perfect gas would, of course, require more energy to accelerate the molecules, to take up their liquid state; and we know it requires considerable energy to convert this condensed or partially condensed product into a gas.

Percy H. Thomas: As in the case of the pith-ball and charged disk?

Elihu Thomson: It may act as a convector or absorber, and may be ionized more readily also.

Percy H. Thomas: That seems reasonable.

This loss is one of the most difficult scientific measurements the engineer has to make—the measurement of true losses at very low power factor and high tension. The method thus becomes of extreme importance. Mr. Mershon has taken very great pains to get a good method, and to check it in all ways possible. In the absence of further data I do not see any reason to expect any error in it, but I do not feel fully convinced, by his check measurements alone, that he has eliminated all possible sources of error. I do not mean to say I suspect any error, but I do not quite consider these checks themselves wholly conclusive.

I wish to suggest another method of making these measurements quickly, which I have tried, and which I consider much simpler in many ways. This is an old method for high-tension measurements—the use of the quadrant electrometer as a wattmeter. Such an instrument was discussed by Miles Walker in a paper read before the Institute at the Annual Convention in 1902, under the title of "The Electrostatic Wattmeter in Commercial Measurements." The description of certain measurements made with this wattmeter will be found in a paper presented by me at the Annual Convention of the Institute in 1905, entitled "The Experimental Study of the Rise of Potential of Commercial Transmission Lines, Due to Static Disturbances Caused by Switching, Grounding, etc."

One other suggestion. Often the best method to eliminate a good many of the difficulties is to use a large-capacity apparatus. It is a great handicap to start off with a small transformer in large work, as it is necessary to correct for the errors introduced by the transformer itself. If it had been possible to use a 1,000-kw. generator, and a 1,000-kw. transformer, a great many of the possible causes of error would not have had to be considered.

There are some minor points I would like to bring forward.

I would like to ask Mr. Mershon if he has any numerical figures on the actual loss during a rain storm?

Some of the vapor-product series are straight lines—those which show the loss on insulators—and others are given as curves. The points are such that it is difficult to tell whether they should be drawn as curved or straight lines. Is it possible they should all be drawn as straight lines?

The losses on the insulator with the pin and without the pin are given. I think Dr. Thomson brought out the point there, that the discrepancy may be due not only to the greater distance the charging current has to come without any pin, but to the presence of loss in the dielectric itself. The dielectric loss may be the cause of the decreased loss with the pin removed. When the pin is in, there is a greater concentration of potential on the head of the insulator than in the other case, and that, as is well known, may cause very serious losses in the dielectric when the concentration is somewhere near the puncture point.

There is another difference between Mr. Ryan's method and

Mr. Mershon's, if I remember, Mr. Ryan projected the vertical part of the loss curve down, to get the critical point, while Mr. Mershon estimates the point of tangency. I may be mistaken, but if I am not, there should be quite a difference in the critical point obtained from the same curve by the two methods, and each method should be judged by its own results. When this is considered, the discrepancy appearing between Ryan's and Mershon's curves would be very materially reduced.

I would like also to ask how the points fall on the loss curve above the knee of the curve. The points given do not run up around the knee. It would be interesting to know how well they fall on the curve above the knee.

Ralph D. Mershon: Fig. 22 gives that.

Percy H. Thomas: That is just around the knee?

Ralph D. Mershon: They come very much closer.

Percy H. Thomas: That seems to me remarkable. It would be interesting to have the insulator, *A*, identified, or a more complete drawing of it given. That is the insulator which shows the least loss.

I would like to ask also whether there is any possibility that the losses in the cords from which the wire was held would affect these curves at all? Of course, that loss is pretty small, but if the cords stayed out in the atmosphere even one day, there might be some change.

Ralph D. Mershon: A check was taken on the cords each time.

Percy H. Thomas: It is interesting to link this phenomenon with the usual brush discharge. With needle points, separated somewhere near the sparking distance of the applied voltage, there is a strong brush discharge, and there is an enormous loss. If the distance is not too small—say three feet—the sparking distance will be almost the same with point terminals as with spheres or other large-diameter terminals. This result is different from the results which are given in Mershon's curve, which we still believe to be right, wherein the smaller-diameter conductors show a much larger loss than the larger conductors. These two results must certainly be consistent, and probably indicate a loop curve in the form shown in the figure. If we have transmission lines separated say 29 inches, as the closest distance we have in the paper, the loss with different size conductors varies considerably, but with any given conductor will increase as the distance is decreased, until puncture finally occurs. I imagine we can draw the loss curve for a small conductor as the voltage increases, as shown somewhat by the full line. For a larger conductor the loss does not start at so low a voltage, but it does rise in the end as shown in the dotted line, and judging from the fact just stated that needle points and spheres have equal puncture distances, these two curves approach each other. The explanation probably is that as the smaller conductor begins to discharge actively the strain is transferred from the conductor itself to the region of air around it, and is then restrained there. At a little higher voltage, or closer distance, the larger-diameter conductor begins to discharge current, and is then on an equality with the smaller. After this critical starting point is once reached, it is the convective resistance of the air which determines the leakage to the air. If this hypothesis turns out to be true, it will probably be found that the loss curves for the smaller and the larger conductors approach each other as the puncture points come nearer and nearer. Of course, that is beyond any practical limit for commercial work.

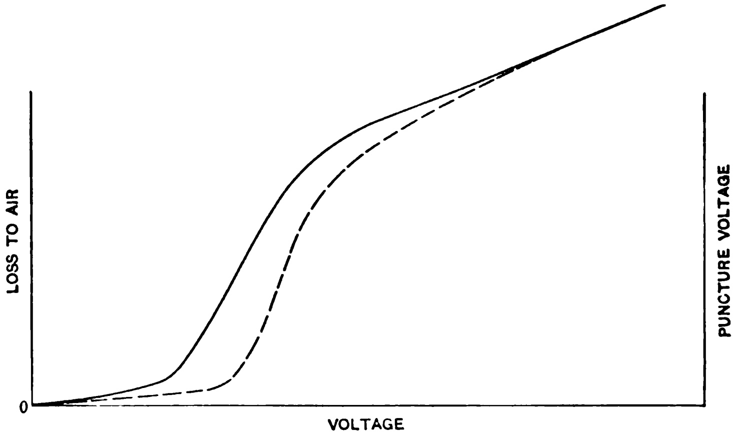


Fig. 1

P. M. Lincoln: A question has occurred to me the answer to which I do not find in the paper—and that is the question as to the influence of the potential of the ground with respect to the potential between wires. Mr. Mershon's curves are all plotted with reference to the potential between the wires. If he was working with a single phase, as I assume he was, then the ground potential may safely be assumed as half the potential between wires. However, in a three-phase system the potential to ground does not remain one-half of the potential between wires but approximately 58 per cent. of it. The question occurs to me, whether or not this difference of potential has any effect on the loss which will take place in these wires. Again, in case a three-phase system becomes grounded, what effect does that have on the loss? Will the loss be decreased or increased? The potential between the wires will remain the same, but the potential of the conductors to ground will be very different. That is quite an important question, and has an important practical bearing.

Carl Hering: While at Niagara Falls some ten or a dozen years ago I noticed a phenomenon which may have some bearing on a point raised in the paper, and touched on by Professor Thomson and Dr. Sheldon, namely, on a possible loss of energy into the space surrounding the high-tension transmission wires. I was riding on a steam train which was close to the high-tension transmission lines, and the smoke or steam from the locomotive passed across these lines. As it crossed the wires, I noticed that it formed itself into circular rings around the wires as centers. Presumably they were hollow cylinders, but I could see only the ends, which were circles. It was quite a striking phenomenon. I called it to the attention of a number of those near me, and they all perceived it. It was at the time of one of our conventions. It seems to me this shows at least two things, namely, that some phenomenon takes place requiring energy, to arrange the smoke into rings, and that this energy must come from the wires, and therefore represents a loss; it may be trifling, but it is a loss.

Chas. F. Scott: Mr. Mershon's paper deals with certain large and fundamental questions and combines in a very beautiful way the scientific and the engineering. It records a research into unknown fields—not a simple measurement of some facts pretty well outlined beforehand, but an investigation into an unknown field where unexpected results have been obtained. The unexpected very often appears, at first, to be the erratic. If the points do not fall on the curve properly, it seems at first that there are probably some errors of measurement, or instrumental errors. The errors of observation having been eliminated, and the discrepancy still occurring, then it is necessary to look for some new factor. Mr. Mershon intimates some of the troubles he had in discovering these new and erratic elements, and it seems to me that one of the most beautiful things in the paper is the manner in which he set about to discover what was the matter with the vapor. He was pretty sure beforehand that the vapor had not anything to do with the case. His former tests and Professor Ryan's tests had apparently established the fact that the vapor was not a variable factor, but when he finds troubles, he begins to investigate as to the vapor. He does not know what the law is, but he sets his assistants to work to make all sorts of new combinations of vapor constants, and they finally fall upon one which seems to account for and explain the phenomena observed. The law may admit of scientific explanation, and in short be quite obvious now that it has been discovered. The point I want to make is that Mr. Mershon worked in the dark, and worked with no guide, and he finally came across this " obvious " conclusion.

Another thing is brought out in the same connection—a matter which can be worked out in the laboratory and measured under laboratory facilities and laboratory conditions may unfortunately, and sometimes in a very discouraging way, prove ineffectual and incomplete when it gets out on a practical transmission line. Lightning arresters may be cited, and observations and measurements like those of Professor Ryan—not because the laboratory may not have gone as far as it could, but because it cannot anticipate all the outside conditions.

This paper, and the things it deals with, are fundamental, because they set certain limits to electric power transmission. Mr. Mershon in another paper, which he worked out with great elaboration some two years ago, sets forth the economic voltage to be applied for transmission to different distances, and the size of conductor which would be used in transmitting power to different distances with the greatest economy. It happens that the diameters of conductors to be used with certain voltages, at certain distances, all fell within the limits of loss. For example, a wire half an inch in diameter was determined by Professor Ryan to have a loss beginning at a certain critical voltage. Mr. Mershon found it was not desirable to use that wire at that voltage, but at a lower voltage. That seems to be a happy circumstance. It would be quite unfortunate if it were necessary, for example, to use a wire an inch in diameter to avoid loss at 25,000 volts.

Now, Mr. Mershon has unfortunately changed one set of these constants, the critical voltages for wires of different diameter, and I am not sure from my recollection of the other paper whether he can now use the diameters of conductors which he found in his paper on transmission economics were desirable. If he can touch on that in his résumé, it will be quite interesting.

This brings into prominence another point, the difference between aluminum and copper. He says in his Conclusion 18 that "The loss and critical point are the same for copper and aluminum under the same conditions." That statement refers presumably to the same conditions of diameter, and not of conductivity, so that in practical work there may be a very marked difference between the use of the two metals, favorable to aluminum.

This paper marks another chapter in an interesting history which has been going on in the Institute TRANSACTIONS for the past ten years. To give a résumé for a moment—a dozen years or more ago, when large transformers of high voltage seemed to be something in the future, a high-voltage transformer giving 40,000 volts was made for the testing of insulators and for a general investigation into unknown regions of high voltage. In these tests, made at Pittsburg, some small wires were strung four or five inches apart, which showed a critical point, a very decided critical point, at which the wires began to give manifestations in three different ways, appealed to three different senses: to the eye by the corona and halo around the wire, manifested in the dark, to the ear by sound, and to the sense of smell by the odor of ozone or something of that character. These three indications began to manifest themselves at a certain voltage which could be read very closely on the voltmeter, and the manifestations could be repeated in successive tests. Mr. Nunn was in Pittsburg about that time. He was then operating the oldest high-tension single-phase transmission, and was very much interested in these tests, and urged that tests of that kind be continued out at Telluride, offering the facilities of the power plant with the facilities of the apparatus and assistants and observers which were furnished from the east. A little later Mr. Mershon did the work which has been recorded in the Institute TRANSACTIONS, to which he has referred this evening. Professor Ryan became interested in these results. He wanted to get a scientific explanation, a law, and he carried on a very beautiful set of experiments which have been recorded in the papers which he has read and to which Mr. Mershon has referred.

Mr. Mershon has taken up the subject again, and has been able to draw some new conclusions. I think it is hardly worth while to add to the endorsements which have already been given to research work of this kind, which unite so closely the scientific, the engineering and the commercial. We can hardly realize the difficulties which Mr. Mershon has encountered. He has referred to them, with that little smile of disgust which he had a while ago, when he referred to the fact that he had to throw away some six months' tests, because something had been overlooked; but all of us who know Mr. Mershon and have known him for years back, know of his strong persistence, and that he does not stop at any ordinary obstacles.

A. E. Kennelly: While desiring to add my tribute to the great merit and value of the paper, I would like to ask a question on one of the points that seem difficult to understand. I refer to the effect of stranding the conductor upon the critical voltage. If I understand Figs. 39 and 42 correctly, the relation between critical voltage and outside diameter of the conductor is substantially the same for the solid wires and for the seven-strand wires. When, however, we come to 19-strand and 37-strand wires, there is a departure from the relation, and the critical voltage increases as though the diameter of the multiple-strand wire had been enlarged. In other words, do I understand the results correctly in deducing that the effect of stranding is only shown in 19-strand and 37-strand wires; and is not shown in seven-strand wires, which behave like solid conductors?

Ralph D. Mershon: Apparently the seven-strand conductor is equivalent to the solid, for the same extreme diameter, but No. 7 is 19-strand and No. 8 is 37-strand.

A. E. Kennelly: That is, the difference begins between seven strands and nineteen strands.

Ralph D. Mershon: Dr. Kennelly's understanding is in part correct and partly in error. The effect of stranding *is* shown in a seven-strand cable. The effective diameter of a seven-strand cable (that is, the diameter as regards critical point) is apparently that corresponding to the diameter of a solid conductor whose diameter is equal to the outside diameter of the seven-strand cable. The outside diameter of a seven-strand cable is greater than the outside diameter of a solid conductor *having the same carrying capacity*. The effect of stranding, therefore, in a seven-strand cable is to increase the effective diameter. When, however, the cable has more than seven strands, the effective diameter is apparently greater than that of a solid conductor having the same diameter as the extreme outside diameter of the cable. In other words, the seven-strand cable appears to have an effective diameter greater than that of a conductor having the same carrying capacity, and equal to that of a solid conductor having a diameter equal to the extreme diameter of the seven-strand cable; while, with more than seven strands, not only is the effective diameter greater than that of a solid conductor having the same carrying capacity as the cable, but it is even greater than the extreme diameter of the cable. Why this should be the case I am unable to conjecture, unless it be that the smaller the strand used, the smoother and more polished the surface of the strand, because of the greater number of times it has been drawn through the die. Now, we know that the smoother the surface of a solid conductor, the higher is the critical point, and it may be that while the corrugations on the surface of the cable, due to stranding, are too large to amount to roughness, the smoother surface of the individual strands is effective in increasing the critical point.

Before replying to the other speakers I wish to ask Dr. Thomson with reference to Fig. 40, to see whether he has any suggestions to make in regard to that part of the subject.

Elihu Thomson: It is simply a question of the advisability of carrying to extremes the tests that are there shown. Quoting from the paper: "In Fig. 41 corresponding results have been obtained for different sizes of conductors at the same spacing. Here again, the residual differences do not differ widely, except at the high voltages where the loss is very sensitive to any change of condition, such as smoke, etc. On comparison also it will be seen that the residual differences are about the same in the two figures. Apparently, therefore, the increase of loss due to the increase of vapor in the atmosphere is the same for the same vapor product no matter what the size of conductor or what the spacing between conductors. Why this should be the case, I am unable to conjecture, any more than I am able to arrive at any rational explanation of the relation between loss and vapor product." It seems to me it would be desirable that these tests be carried to extremes, to see whether the condition pointed out will hold through much wider ranges.

W. L. Waters (by letter): I think Mr. Mershon's paper on the losses in high-voltage overhead wires and insulators is the most important paper which has been presented to the Institute this year. Only those who have undertaken similar investigations realize the amount of work which is entailed in such an investigation. Mr. Mershon is greatly to be complimented on the perseverance and skill with which he has continued the investigations which he began twelve years ago.

There is just one point which I wish to discuss in connection with this paper, and that is the general question of insulator loss. Mr. Mershon finds that the insulator loss is considerably greater with wooden pins than with iron pins, and the explanation of this fact given by him does not altogether explain why we get much better results with some insulators with wooden pins than with iron pins. Mr. Mershon in his explanation considers the insulator as a condenser of infinite resistance in series with the resistance of the wooden pin. As a matter of fact, however, the insulator has not an infinite resistance, and under some conditions can have a comparatively low resistance. A more exact way would be to consider the insulator as a condenser with a considerable amount of leakage, in series with an ohmic resistance. There is leakage between the various parts of the insulator, both through the material of the insulator and over the surface. Assuming this state of affairs, the correct diagram is shown in the accompanying sketch, in which I have taken the system as consisting of a high ohmic resistance shunted at various points by condensers. We see from the vector diagram that the ohmic drop in the wooden pin is not in quadrature with the terminal voltage but makes a smaller angle, say 45 deg. or 60 deg., with it, consequently the voltage on the insulator is appreciably lowered by the use of the wooden pin, as shown in the vector diagram. The voltage from line to ground is $O E_1$ while the voltage on the insulator is $O E_2$, so we can understand why an insulator which will stand up satisfactorily with a wooden pin may not be able to stand up under the increased voltage to which it would be subjected when used with an iron pin. Of course,

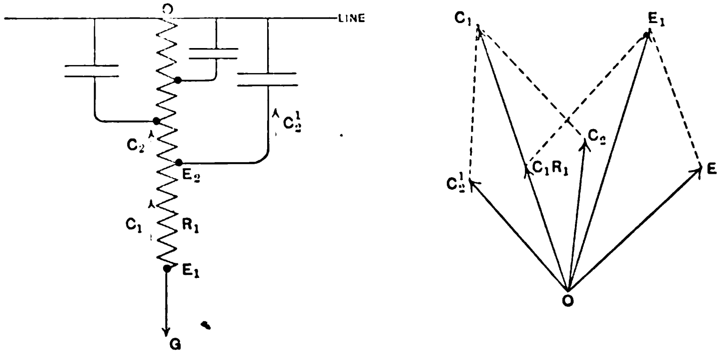


FIG. 1

it is impossible to say just how much the voltage would be reduced, in any individual case, without making measurements. Probably Mr. Mershon has figures from which he can calculate the reduction in voltage. The ohmic loss in the wooden pin is $C_1^2 R_1$ and the magnitude of this loss will decide whether there will be any trouble due to overheating of the pin; and the variable resistance of the pins on the line will account for the fact that some pins give trouble due to burning while others do not.

It will be seen from the above that the capacity and ohmic resistance of the insulator, and the ohmic resistance of the pin, together decide the success of the wooden pin in any particular case, and I would suggest that on account of the experience gained from Mr. Mershon's tests that Mr. Skinner add to his insulator-testing specifications a clause requiring measurement of the average ohmic resistance and electrostatic capacity of the insulators, and the ohmic resistance of the pins when of wood. These values could probably be determined without much trouble, when the insulators are tested in large numbers, and after we have a little more experience in regard to actual figures they would give us some idea as to the probable success of the insulators and pins.

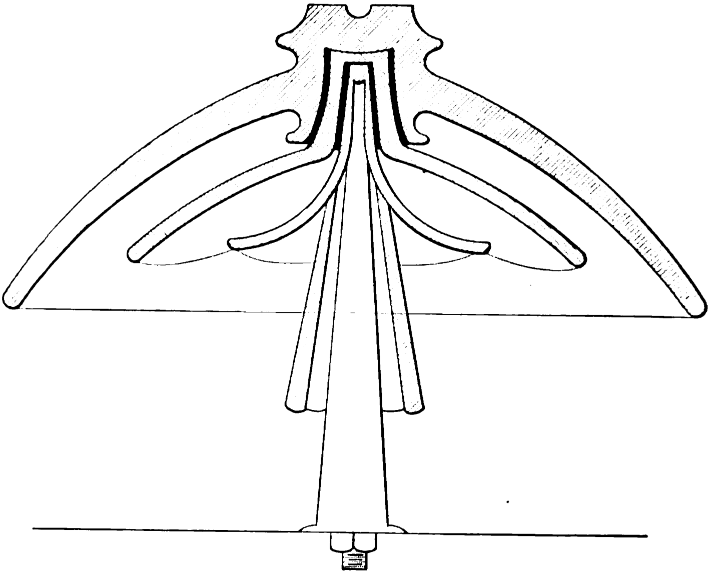


FIG. 1

N. M. Snyder (by letter): From observation and personal experience I concur with Mr. Mershon—especially in his Conclusions 13 and 14.

I also believe that the loss over insulators by moisture may be reduced materially by a change in design, and Conclusion 14, for example—The smoother the surface of a conductor the less the loss and the higher the critical point—seems to suggest a remedy. It is quite true, that a point or number of points on a highly charged body will dissipate a charge more quickly than if the body were entirely smooth; and by a series of tests we find that a charge will remain on the exterior rather than the interior of a conductor.

Now, then, by so designing an insulator as to give the main feature the shape of a cone, as shown, to give a protection to the petticoat and pin from rain, the insulator would have the advantage that the surface would be comparatively free from points to radiate a discharge, and also that the inner petticoats would be protected to a certain extent from moisture, coal-smoke deposits, etc. By this arrangement I believe additional benefits may be derived.

Ralph D. Mershon: Before replying to the technical points raised, I desire to emphasize the appreciation, already expressed in my paper, of the generosity of those who contributed to the expenses of this work; and to express my gratification at the expressions of like appreciation which have come from the various speakers this evening. It is to be hoped that the engineering profession may be benefited by similar contributions in the future.

The interest which Professor Thomson has taken in this matter, and the thoroughness of his discussion are very gratifying, especially as he has thrown a great deal of light upon the relation between loss and "vapor product." In fact, it seems to me most probable that his explanation of this relation is the correct one.

Mr. Floy has brought up the question as to why the critical points obtained by me differ from those obtained by Professor Ryan. I think that his suggestion, especially if extended a little further, may largely account for this difference. Professor Ryan determined his critical points by the criterion of luminosity. There might have been, as suggested by Mr. Floy, an error in this method of determination, due to the personal equation, and to the conditions under which observations were made. But there is another possibility. Luminosity would require a certain definite amount of loss; that is, it would be necessary to be a certain distance above the critical point before luminosity would occur, and it may be that it is necessary to go quite appreciably beyond the critical point before the wires are luminous. There are two other considerations also which might, in part, account for the difference. One of these, touched upon by Dr. Steinmetz, and which I shall refer to again, is that Professor Ryan in his experiments, undoubtedly realized the condition of a conductor having a uniformly smooth surface a great deal closer than it would be possible to realize this in a transmission line. The other is that Professor Ryan's experiments were made under such conditions as would give him as nearly uniform density of charge on the surface of the conductor as it is possible to obtain. Now, if instead of making the measurements between a conductor and a cylinder which surrounds it, they are made between two conductors, there is not a uniform distribution of charge on the surfaces of the two conductors. It is true that when the distance between the conductors is great as compared with their diameters, the charge is very nearly uniform, but, nevertheless, it is not exactly uniform, the density being very slightly greater on those portions of the conductors opposed to each other. This difference of charge means an increased rate of fall of potential, which increase, though very slight, would aid somewhat in lowering the critical point, and, therefore, in the discrepancy in results.

Dr. Steinmetz has said that the critical point as determined in my paper is not the true critical point, for the reason that the conductor and surrounding conditions are not absolutely uniform; that the first beginning of a brush discharge will be at some isolated point, some kink in the conductor, and that the voltage at which this occurs cannot be considered as the voltage where the breakdown strength of the system has been reached all over the conductor. The point Dr. Steinmetz raises is a very interesting example of the difference between engineering investigation and scientific investigation. The critical point I have determined in my paper is the engineering critical point of a transmission line, and is the critical point with which transmission engineers are concerned. The critical point of which Dr. Steinmetz speaks is the scientific critical point, and while it is very desirable to have it, after it has been obtained, it will be impossible to make use of it in transmission practice until there has been determined the corrective factor necessary to account for the " kinks " and " surrounding conditions " which will exist in practice. I quite agree with Dr. Steinmetz that it is very interesting and very desirable to have the scientific critical point, but I maintain that for transmission purposes the critical point as I have derived it is the one most immediately desirable and which we must have in any case. It is possible for us to get along without the scientific critical point, but the engineering critical point is absolutely necessary. Later on, I expect to continue this work, and at that time I shall endeavor to obtain the scientific critical point.

Dr. Steinmetz also takes exception to the method I have employed for determining the critical point; that is, by extending the lower limb of the loss curve and finding the point at which the upper limb departs from it. He says that both branches of the curve may theoretically be expected to go through the origin, and that if we had the equations of the lower branch in Fig. 38 and of the upper branch, the point of intersection would be the critical point. I do not see how these statements can be correct. The whole theory of critical voltage, as I understand it, is that the equation of the upper branch does not go through the origin; that the phenomena to which the upper branch is due begin more or less abruptly at the critical voltage. If this be the case, the critical point is the point at which the equation of the upper branch would cut the axis of voltage and is, therefore, in the curve formed by the combination of the upper and lower branches, the point of departure of the upper from the lower branch, and not, as stated by Dr. Steinmetz, the point of intersection of the equations of the upper and lower branches. Resort to the device suggested by Dr. Steinmetz, of plotting the logarithms of the ordinates, does not lead to satisfactory results. The upper portion of the curve obtained is not a straight line, so that if the endeavor is made to determine the critical point from this derived curve, it can be done only by resorting to the same method that I have employed; namely, that of determining the point of departure of the upper from the lower limb. In the derived curve, this method is more difficult of determination than in the original curve, because the rate of departure is less.

As regards the method of measurement used and the remarks made thereon by Mr. Thomas. I would say that while I have not used the particular method he mentions, I have made use of some methods of measurement involving a wattmeter in the high-voltage circuit, and found them extremely unsatisfactory. The chances for error due to electrostatic effects and other effects incident to the use of high voltage directly, are so great, especially when measuring losses as small as those concerned and at the very low power-factor at which they occur, that the use of instruments in the high-voltage circuit does not commend itself to me. On the other hand, having used the present method of measurement in the Telluride investigation, and having made use of it again in the Niagara work with entirely different apparatus, I have come to feel, as the result of such check measurements as could be made, and in view of the compatibility of the results obtained, that this method is absolutely reliable. In addition, it has to commend it the fact that one is working in a low-voltage circuit instead of a high-voltage one. I would say in reply to Mr. Thomas' question, that I have some data for losses which occur under rain conditions, but they are not definite enough to justify their presentation. During a rain storm or a snow storm the wattmeter continually varies with little jerky kicks. Mr. Thomas notes that the "vapor product" curves for the insulators are straight lines, while those for the loss between conductors are curved. As stated in the paper, the loss lines for the insulators would probably have been curves also if the readings had been carried to a higher vapor product. This was not done, because of the great expenditure of time that would be involved in waiting for weather conditions which would enable measurements under the higher vapor product conditions. Mr. Thomas also refers to Professor Ryan's method of determining the critical point of a loss curve, and thinks that this might in part account for the discrepancy between my critical points and those of Professor Ryan. While there would, undoubtedly, be a discrepancy in the critical points determined in these two ways, this would not, I think, account for the discrepancy which exists, for the reason that the critical points finally given in Professor Ryan's paper were obtained not from loss curves—as I remember it he took no loss curves—but from his observations as to critical point as determined by luminosity.

Mr. Lincoln inquires as to the influence which the potential of the ground relative to the wires might have on loss, with particular reference to the losses on a three-phase circuit, as compared with those on a single-phase circuit. My measurements were all made on a single-phase circuit with the neutral grounded, so that I am unable to reply to Mr. Lincoln's question. I hope, however, to be able to supply this information later, as the three-phase loss is one of the matters which I have in mind for future investigation.

Replying to Mr. Scott's remarks, as to the bearing which these new critical points would have upon the conclusions arrived at in the paper which I wrote for presentation at the International Electrical Congress, I would say that the economic voltages of the International Electrical Congress paper are all well below the critical voltages of the present paper. I agree with Mr. Scott that in the use of higher voltages there may be a very marked difference in favor of aluminum, because of greater diameter of conductor corresponding to a line of given resistance.

Ralph D. Mershon (by letter): There is one point in Professor Thomson's discussion with which I do not agree, and which I feel sure is in error. He assumes, in discussing Conclusion 19, that the only insulator loss which could vary with frequency would be the hysteresis loss in the body of the insulator itself. I do not consider that this would be the case, and my attitude in regard to this matter will be clear from what follows.

The losses which, as I take it, occur in connection with an insulator, are as follows:

a. I^2R loss through the substance of the insulator itself. This is the same sort of loss that would occur with direct current of the same effective voltage.

b. Hysteresis loss in the substance of the insulator itself, due to the variations of dielectric stress which occur with alternating current.

c. I^2R loss in the film on the surface of the insulator, similar to that which would occur with direct current.

d. I^2R loss in the film of the insulator due to the charging or condenser current taken by the insulator.

I think there can be no question that film losses or something equivalent thereto exist. The fact that insulator losses are different for different hygrometric conditions is proof of this, so that there will probably be no dispute as to the existence of the loss (*c*). That there should be a loss of the nature of (*d*) would appear from the following consideration. The different petticoats of the insulator and the different portions of these petticoats are undoubtedly at different potentials. The result is that between the various petticoats and portions of the same and between the petticoats and the insulator pin there is a condenser action; that is to say, the petticoats are analogous to the plates of condensers in series. To make the analogy more nearly exact, we must consider that between the condensers in series there are resistances because the charging current to the various portions of the petticoats must come to these portions through the resistance of the surface film of the insulator. Thus, the charging current to the insulator will cause I^2R loss in the film on the surface of the insulator. Now, the magnitude of this charging current will depend upon the frequency, and the I^2R loss due to this charging current will, therefore, depend upon the frequency, so that the insulator loss would be affected by frequency, even though the hysteretic loss, or loss (*b*), were zero. It was not loss (*b*) that I had in mind in Conclusion 19, but rather loss (*d*). I do not, therefore, agree with Professor Thomson that "if the insulator dielectric were free from all dielectric hysteresis, we should not expect Conclusion 19 to hold." Aside from the above theoretical consideration, that there is a loss of the nature of (*d*) is evidenced, I think, by the fact brought out in the paper that of the various insulators measured, some of the larger ones had the higher losses. We would expect that the larger the insulator, the smaller would be losses (*a*), (*b*) and (*c*), but that loss (*d*), if it exists, would be greater, since the charging current would increase with the size of the insulator, and the increase would be especially marked in insulators whose petticoats were approximately parallel to each other and to the pin. As pointed out in the paper, the measurements seem to bear out these two considerations, and it was because of this fact, and because it seemed to me that the loss in the substance of the insulator would be small, that the difference in the losses shown by the two curves in Fig. 32 was assumed as mainly due to loss (*d*). It has been suggested that this assumption is in error and that a large part of the difference in loss shown in Fig. 32 may be due to (*a*) or (*b*) or both of them.

Since the presentation of this paper, Mr. C. E. Skinner has very kindly had made for me some measurements bearing upon the ohmic resistance of an insulator similar to that to which Fig. 32 applies. He found that with a galvanometer connected in series with the insulator and with 500 volts direct current impressed upon the combination, no indication was obtained, although the galvanometer was such as would, on 500 volts, give an indication with 500,000 megohms in series with it. It would seem, therefore, that this definitely settles the question as to I^2R loss in the substance of the insulator, to the effect that such loss is practically zero. As to the hysteresis loss, I am not in a position at this time to make any measurements bearing upon it, but expect to do so later. Meanwhile I have no reason to believe that any large portion of the difference in loss shown by the two curves in Fig. 32 is due to hysteresis.

I do not see the force of the point Mr. Waters makes. Even if the insulator were a perfect condenser with no loss, a pin would increase the insulation strength, if it had sufficient resistance, and would also be a source of loss. The fact that the insulator is not a perfect condenser is shown by the measurements upon it. The loss is mainly, if not entirely, over the surface of the insulator. Possibly Mr. Waters has been misled in considering Fig. 37 by having overlooked the fact that, as stated in the paper, the pin, with which the curves of Fig. 37 were obtained, had to be wetted in order to make the measurements.

DISCUSSION ON "THE TESTING OF HIGH-VOLTAGE LINE INSULATORS." ATLANTIC CITY, N. J., JUNE 30, 1908

(Subject to final revision for the Transactions.)

Percy H. Thomas: The testing of a high-voltage insulator by application of voltage from a spark-gap or other high-frequency discharge has an extremely important bearing on the type of insulator. A four-part insulator or a three-part insulator, in fact any large insulator, has its resisting power made up of a number of elements all practically in series. The possibility of the concentration of potential on certain parts of these insulators is well recognized. This condition is recognized as greatly reducing the breakdown voltage of an arrester. The feature I wish to bring out is that with very high frequencies this concentration effect is enormously multiplied. I believe that a careful study of this matter will result in some modification of insulator design.

I ask Mr. Skinner if it is worth considering that there will be a difference in local heating, according to the frequency of the test current; for example, a 133-cycle test might show local heating which would not show on a 25-cycle test. Any local heating in a specific insulator is a very important item, as it indicates an inside weakness.

Ralph D. Mershon: Mr. Skinner's paper interests me not so much because it suggests specifications for an insulator as because it recommends certain definite methods of test. There is one recommendation especially with which I heartily concur; that is, make rain tests by using, in all cases, a vertical spray and placing the insulator at a specified angle, instead of endeavoring to imitate rain conditions as regards the angle of precipitation.

Rain conditions are indefinite and variable, so that any assumptions made in regard to them must necessarily cover only one of many conditions. The best that can be done is to assume a maximum rate of uniform precipitation at a definite angle. We know, with a fair degree of accuracy, the maximum rate which will not be exceeded in practice. The angle of precipitation may, however, vary from approximately zero degrees with the horizontal to 90°. It is usual to assume 45° as a fair compromise. But having made these assumptions, which can not represent all actual conditions, we are unable accurately and conveniently to produce them. It is extremely difficult to get a water spray to fall at any definite angle, other than 90° with the horizontal, and with uniform precipitation. The result is that flash-over tests made by different observers with different testing equipments, or even at different times by the same observer with the same equipment, are often most discordant.

It seems to me it would be much better to adopt a method of test which, whether it does or does not appear to represent very closely actual conditions, will serve as a criterion and will offer some chance of reproduction, approximately at least, at different times and with different observers. This will be accomplished if the spray be kept vertical, and the insulator inclined, for there is a great deal better chance in that case of obtaining a uniform spray at a definite angle with respect to the insulator.

The present method of testing insulators for flash-over conditions under precipitation is very unsatisfactory, so far as repetition is concerned. I have lately made some experiments on a new type of insulator under what was supposed to be a precipitation of one inch in five minutes at an angle of 45°. About a week afterwards another observer made similar tests under as nearly as possible similar conditions, and obtained the same results. About three weeks afterwards the same man endeavored to repeat the results and could not get anywhere near the figures which had been obtained in the first place for flash-over under rain conditions. I have had similar experiences repeatedly and, as the result, have usually, when desiring to compare two insulators as regards flash-over, endeavored to test them together, either simultaneously or by keeping the spray the same and alternately substituting one insulator for the other. The latter is probably the safer method, as more likely resulting in the same precipitation in both cases.

I am disappointed that Mr. Skinner has not gone more fully into the question of the kind of spray nozzle for producing a uniform precipitation. It is difficult to get a nozzle which will give uniform distribution and do so continuously. It would be of great value if Mr. Skinner could tell us where or how to obtain a nozzle which would fulfil the requirements.

The rate of precipitation usually assumed is about one inch in five minutes. The maximum rate of precipitation of which the United States Weather Bureau has any record is less than eight-tenths of an inch in five minutes. Something more than the maximum observed rate is desirable, and it would seem, therefore, that one inch in five minutes would be amply sufficient. I would suggest that this figure, or its equivalent, two-tenths of an inch in one minute, be adopted, instead of the range of precipitation which Mr. Skinner has suggested.

I agree with Mr. Thomas that frequency will, in all probability, have a considerable effect on the flash-over voltage of the insulator; if this is shown to be the case, the insulator should be tested at the frequency for which it is designed. The flash-over voltage will also probably depend a good deal upon the method of voltage control in making the test. The discordant results obtained with different testing equipments are, no doubt, due, in part, to the fact that the voltage is usually controlled by means of a rheostat in series with the testing transformer. This method of control will, under some conditions, materially modify the wave-form. If the voltage be varied by varying the field of the generator, there is a much better chance for concordant results.

Clayton H. Sharp: In reference to the production of a proper spray or precipitation for use in the testing of insulators, I am having constructed at present an apparatus which has been suggested by an arrangement in use, I believe, in the German Reichsanstalt. This arrangement consists of a large cylindrical vessel, which has a considerable number of little tubes running out from the bottom of it, equally spaced in centers of one and one-half inch squares. The top is closed and has a micrometer valve by which the admission of air can be controlled. On the side there is an ordinary gauge glass to show the level of the water, and the rate of precipitation. These tubes will have cotton wicking stuffed into them of proper thickness, and a tail of fine wire, to enable the drops to fall off. With an arrangement of that kind, I hope to get a uniform dropping of the water, in other words, an imitation of a rainstorm, which can be regulated by changing the admission of air by the valve, and in which the rate of precipitation can be measured on the gauge glass at the side. By setting up a fan at one side the effect of a hard wind may be obtained. I do not know that such an apparatus has ever been used, at any rate in this country; if it has I would like to know what the results of experience with a device of that kind have been. It seems to me that such a device has a great advantage, coming nearer to an actual rainstorm than any ordinary spraying arrangement It gives separate drops of water, and that is what we want.

E. M. Hewlett: Regarding the rain test on insulators, some folks like heavy rain, some like a flood, and some are satisfied with a mist. I do not believe you can satisfy everybody. It looks as though possibly a steam test might give a better average condition; there will not be so many conditions to balance up. You can get quite a film of moisture on the surface with the steam test, and can duplicate it more readily than the rain test, making better average tests. The rain test is of value in determining insulator design.

Chas. P. Steinmetz: There is one test which I do not find mentioned in Mr. Skinner's paper, and that is the test of the insulator after being submerged in water for a considerable period, a week or ten days, or more. A porcelain insulator may well stand all the tests outlined here, and may fail in service after a few weeks or months, by absorption of moisture through hair cracks in the glaze, due to incomplete vitrification or to porosity of the material. Porcelain is by no means an ideal material for an insulator. It is a heterogeneous mass, more or less completely vitrified in its interior, and covered with a glaze. If the vitrification is perfect, it is just as good and uniform as glass, but if the vitrification is not perfect, as long as the glaze keeps the moisture out it will stand, but as soon as by temperature variation of the air the glaze begins to acquire hair cracks, moisture soaks in and the insulation strength goes down. Glass would be preferable except that it is mechanically weak, and is hydroscopic, and so covers itself with a film of moisture. I am not entirely satisfied with such a test as immersion in water, but I bring it to your attention. Perhaps some one else might suggest a better way of testing a small percentage of insulators for absorption of moisture and decrease of disruptive strength resulting therefrom by long-continued exposure to water and atmospheric conditions.

I also raise the question whether it is advisable, as proposed in the paper, to allow any tests of less than twice the rated voltage. Here tests are proposed of one and one-quarter and one and one-half times the rated voltage. Now, you know that in our standardization rules, no voltage test is permitted on any apparatus of less than twice the rated voltage. That is the minimum test permitted. Here we have recommended tests under undesirable, but still actually existing conditions, of one and one-quarter times the rated voltage. The margin is rather small, probably too small. Many of us feel that at the present time the insulator is the weakest link in the long-distance transmission system. The occasional use, for instance, of 60,000-volt insulators on 40,000-volt systems also shows that the engineers feel that the extra high-voltage insulator is really not quite as good, does not have the same margin of safety, as other apparatus. It would be much more consistent if we insisted in testing the insulators to ascertain that they have the same margin of disruptive strength as all other apparatus is supposed to have, instead of so moderating the tests as to allow the insulators to be rated at a voltage to which they are not entitled on the basis of the margin of safety standard for all other parts of the system.

In regard to specifying the number of insulators tested on one trial, etc., my understanding is that the paper proposed additional matter to the rules of our Standardization Committee, so in this connection our standardization rules—which specify how many insulators you can test from one transformer, that is, how large the capacity current can be compared to the tranformer capacity—would apply. All those features that are specified by our standardization rules are implied, and the paper merely brings forward additional matter.

C. E. Skinner: I am a little surprised that nothing has been said in the discussion in regard to the dew test. I do not know whether this test has been used to any great extent or not, but those who have used it claim that it is far more satisfactory than any rain test, and also more severe, and it is one that ought to be relatively easy to repeat.

In regard to the number of insulators which may be tested on a given size transformer, I would say that Dr. Steinmetz has already covered the point. You will note that the paragraphs on voltage control, capacity of testing transformers, etc., are practically copied from the standardization rules. They are partly repeated here, in order to make the specification complete.

In regard to the question of placing the insulator vertically, and having an angular spray, I agree entirely with Mr. Mershon; no method has yet been brought to my attention which could be controlled with sufficient accuracy to allow repetition. This specification is intended to be a performance specification, and to have a performance specification you must be able to repeat your tests. The best we have been able to do in our laboratory in making tests is to get a spray which, measured by the rain gage, taking successive squares in the spray, showed a variation of very approximately that given in the specification, that is, 0.2 to 0.3 inches per minute. I do not believe it makes very much difference whether it is a little more or a little less. I think that with that amount of water the results will be about the same. Mr. Mershon referred to a rate of one inch in five minutes—which is equivalent to 0.2 inch per minute. In all the communications that I received, I did not hear of the method mentioned by Dr. Sharp, although I was in communication with some of the German porcelain manufacturers. As a matter of fact, their letters did not give me very much information in regard to their method of obtaining the spray. I think that it would be impossible to use a fan and blow the spray the same on two successive days—that it would be out of the question to repeat tests of that kind.

The steam test suggested by Mr. Hewlett I think is practically covered by what I called the dew test here. It is merely gotten at in a little different way, and in a way which is frequently met in practice; that is, the insulator is cooled down during the night, and in the morning, particularly in the tropics, and in places where the temperature rises suddenly, the insulator becomes completely coated over its entire surface with a layer of moisture.

The immersion test suggested by Dr. Steinmetz I think would be a very good one to add to the performance test, but I think it would be rather burdensome to make on all insulators.

In regard to the over-potential test of one and a quarter and one and a half times, I would refer to the introduction of the paper in which I disclaim any great responsibility for the data there given; my own idea is that the tests specified are rather too low. I would like to see them higher, and if insulators can be purchased at a reasonable price for use on transmission lines under the more severe conditions, I would like to see the double-potential test substituted for the one given.

Ralph D. Mershon: As regards the dew test, both as suggested by Mr. Skinner and by Mr. Hewlett, it does not seem a definite test. Moist atmosphere—what does that mean? It would make a great deal of difference in the condition of the insulator just how long it is left out, and just what that moist atmosphere means—how can you give any definite condition?

C. E. Skinner: I have not made the dew test myself. It was proposed by two or three other persons who claimed they had made this test and found it perfectly satisfactory. If the air contains a fair amount of moisture, there will be a sufficient collection of moisture on the surface of the insulator to make it flash over, *under the test specified*.

E. M. Hewlett: We have made the steam test, and find it is easier to make the steam test than it is to get up in the morning early so as to find the insulator cool enough to test it with the dew test. We put the steam on the insulator with a hose until the surface is covered with condensed steam, and then make the voltage test.

N. J. Neall (by letter): Routine test. Inspection. I doubt very much the wisdom of allowing so large a variation as ± 5 per cent. in general over-all dimensions from the designed size. This is particularly critical for extra high-potential designs, where an insulator 14 inches in diameter and 14 inches high may have a considerably lower arcing test than one 15 inches in diameter by 15 inches high. I think ± 2.5 per cent. would be safer.

Dielectric tests. This is a good commercial rule for testing parts, but due consideration should be given the potential gradient of the insulator as a whole as well as the individual electrostatic capacities of the parts in series therein. Actually I would expect the top of an insulator to get almost line potential strain, particularly if the pin be grounded. I would call for three times the usual line voltage, 2.5 times is not high enough. There is no designation as to what constitutes a "lot." I should suggest a selective test from each kiln fired.

Design test. This permission to test as many as 5 per cent. is generous indeed. In general, a much smaller percentage than this should suffice.

Rain tests. 1.5 times normal voltage is too low; it should be at least 2 times. Likewise for dew test,—of shorter duration than 5 minutes, say 1 or 2 minutes. In none of these specifications is the important requirement, "with pin grounded," mentioned.

Methods of making tests. Rain test. The proposed angular position of the insulator with respect to a vertical rain does not appeal to me, because the whole combination of static field and reflected rain as found in service is apparently inadequately reproduced in this way. I prefer the rain at an angle instead. This detail requires further working out.

In addition to the preceding details, I wish to add the following: For testing insulators local conductors should be of large diameter to cut down the excessive ionization usually present in such tests. There should be some "table" of the number of insulators of given size that it is permissible to simultaneously test with a testing transformer of given capacity. In testing large insulators in large numbers for extra high voltage, the charging current alone may impair the value of the test. There must be some recognized method of measuring the voltage. Just as soon as the true character of spark gaps is known it should be applied to this work authoritatively. In the meanwhile I would suggest the use of shielded spark gaps with spherical tips—needles being more liable to error and burdensome in practice. For general testing, the voltage by ratio is desirable, provided it can be kept free of error; and the specification as to appropriate size of apparatus might include among its requirements a description of the apparatus.

I have already called attention, in my recent paper on lightning before the Institute, to the desirability of equivalent spark-gap measurements of insulators as indications of their non-arcing power. The arcing-over test of the insulator is no more indicative of its efficiency than the same test on a lightning arrester.

The tendency of the proposed specification seems to be a letting down rather than a stiffening of those requirements heretofore generally followed. I think the record of operation of high-tension transmission systems will show the wisdom of making this element thereof stronger than is proposed in these specifications.

Aside from these criticisms of details, I wish to state my belief that such a specification as here proposed by Mr. Skinner is highly desirable.

DISCUSSION ON "A NEW LARGE GENERATOR FOR NIAGARA FALLS", APPLICATION OF FRACTIONAL-PITCH WINDINGS TO ALTERNATING-CURRENT GENERATORS", AND "MODERN DEVELOPMENTS IN SINGLE-PHASE GENERATORS." ATLANTIC CITY, N. J., JULY 1, 1908

(Subject to final revision for the Transactions.)

Wm. J. Foster: There are two or three points in connection with the generator described by Mr. Behrend to which I would like to call attention. I think that in many respects it is a most remarkable machine. The efficiency as given by Mr. Behrend in the tabulation is something unusual, when we consider that it is a generator of 12,000 volts. I would like to point out how, in my opinion, the high efficiency has been attained.

The writer of this paper has given us a complete assembly drawing. It seems to me that it will be of great value to the professors and representatives of our educational institutions to have such complete data giving every essential dimension. From the curves showing the characteristics, taken in connection with the assembly drawings, it is apparently possible to reproduce the windings exactly. The first thing I notice is the remarkably small amount of magnetic material in the armature, which results in a rotor of unusually small weight, considering the output of the machine. Mr. Behrend has taken a step in advance over all other designers in this respect. The reduction of magnetic material is something that is to be striven for and that can be accomplished, provided we can take care of the heating, which is what has troubled all of us heretofore. The amperage in the slots of this armature is very high, considering the potential, but Mr. Behrend says the temperatures are very low, hence it would appear that the problem has been solved.

A word further with reference to the efficiency. What used to be called the electrical efficiency is evidently given, but it does not include a percentage of the load losses. It simply includes the core losses, which, according to the curve, are 75 kw., or only about one per cent.

The efficiency is unusually high, and has been attained, in my judgment, by using an extremely high armature reaction for a 12,000-volt machine. If you increase the armature reaction twenty-five or thirty per cent, as I consider has been done in this case, you attain a very high efficiency, much higher than has been attained heretofore. But this requires a different design of the rotor, involving a heavier pole. It is evident on the face of it that the pole must be of greater length, to take care of the increased ampere turns. It must be lengthened about as the square of the ampere turns, hence I consider the pole forty or fifty per cent longer than the usual type. This lengthening can be accomplished only by an unusually strong construction in the rotor, which Mr. Behrend dwells upon in his curves pertaining to the peculiar disk construction and in his discussion of the characteristics of the nickel steel. I am especially glad to see that nickel steel can also be obtained of such high permeability. This is another thing which appeals to the designer as a step forward, namely, to be able to obtain nickel steel with high characteristics mechanically, and at the same time very high in its magnetic properties.

In the matter of windage, I am somewhat disappointed in this machine. The curve showing the variation of the friction and windage with the speed is a peculiar one. You will notice how rapidly these factors go up with increased speed. At 300 rev. per min. it is nearly five times what it is at half that speed. If it continues to go up at that rate it will take 300 or 400 kw. to drive the generator at the runaway speed. It seems to me that eddies exist and that the most of the windage is really lost, as far as cooling effect is concerned. What takes place as the speed increases is that a new set or system of eddies is established, requiring more and more energy to enable the speed to be obtained. When we take into account the friction and windage losses in connection with the electrical losses and the load losses, it seems to me there is not very much gain in commercial efficiency on this machine.

The reduction in magnetic material does result in assisting the problem of the bearings, but the bearings must be very conservative with the pressure per square inch as mentioned, and the rubbing speed so conservative. This same diameter of shaft is in use on many generators running at 400 revolutions with which I am acquainted. Hence, the bearings' problem in this Niagara generator is not especially difficult.

B. A. Behrend: I have made the efficiency on the basis of short-circuit and core losses, but not including friction and windage, one-third of the short-circuit losses.

Wm. J. Foster: In working up efficiencies it has been customary to take one-third of the short-circuit losses as the "load losses." I think the Institute should appoint a committee to consider whether that is the correct value to take for the load losses.

L. Schuler (by letter): When the first large turbo-alternators for single-phase current were designed about two years ago by the Felten & Guilleaume-Lahmeyerwerke, the question of avoiding losses by the pulsating armature reaction was carefully considered. It was clearly understood that a minimum of losses could be attained either by perfectly laminating the field or by providing heavy dampers, but we were at that time not quite sure which way would be best. We therefore made the following experiment: An ordinary three-phase induction motor with slip-rings was coupled to a direct-current motor and used as a single-phase generator by exciting one stator-phase with direct current. The other two stator phases could be connected to a variable resistance. Two slip-rings were short-circuited so that the whole arrangement represented a

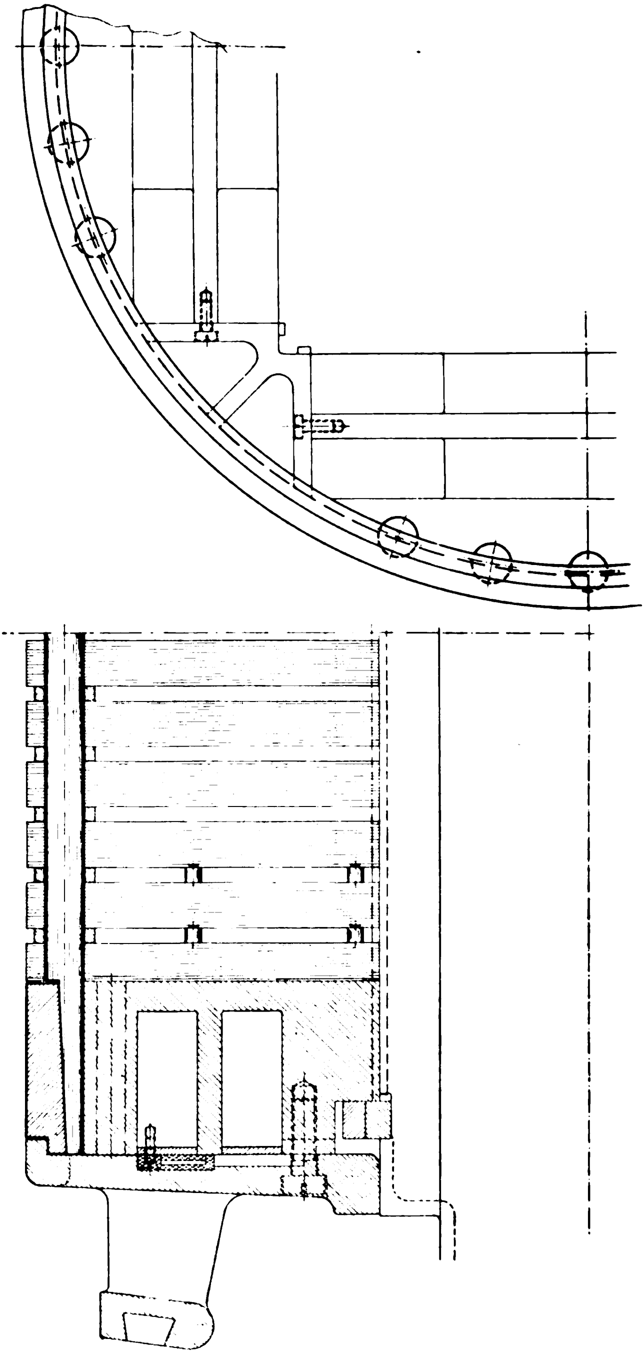


FIG. 1

single-phase generator with stationary laminated field, working under short-circuit. The two stator phases not used for excitation acted as "dampers" when short-circuited. By opening these phases or closing them through the variable resistance it was possible to work the generator with perfectly laminated field or with dampers of variable resistance. The losses were determined by the energy consumed by the direct-current motor. The curve, Fig. 1, was taken with constant armature current. It shows clearly that with single-phase load the hysteresis loss in a perfectly laminated field is much larger than the total hysteresis and eddy-current loss with low-resistance dampers, We therefore used heavy dampers in all single-phase generators.

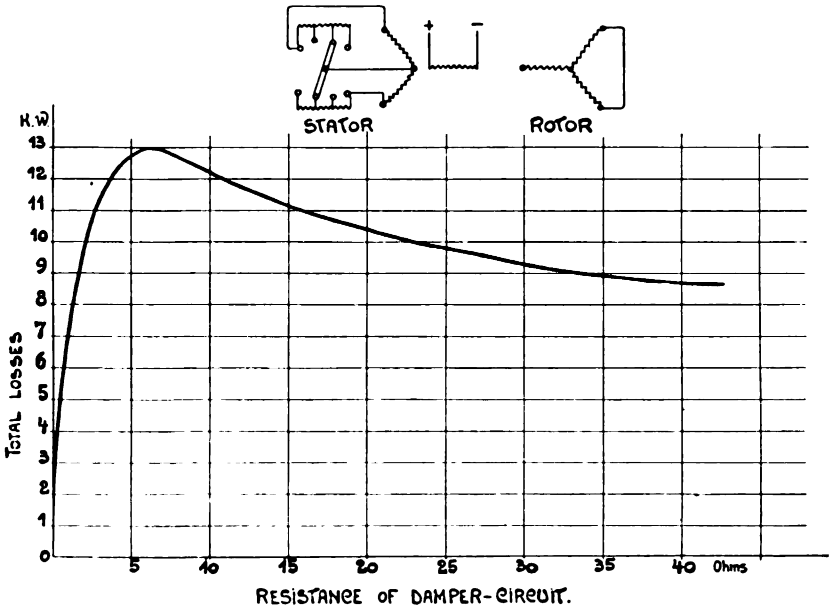


FIG. 2

for which we adopted the design shown in the sketch, Fig. 2, which has given full satisfaction.

F. H. Clough (by letter): I have read Mr. Waters's paper with considerable interest, as probably most of us who have attempted the design of single-phase generators for coupling to steam turbines have experienced the difficulties described and have endeavored to eliminate the deleterious effects of single-phase armature reaction. As the author suggests, the simplest way of looking at the matter is to regard the armature magnetization as consisting of two components, each of half the maximum value and revolving in opposite directions.

If the rotor is provided with a complete squirrel-cage winding, the machine can then be regarded as a single-phase squirrel-cage induction motor. The currents in the rotor bars under these conditions are such that taken in conjunction with the armature reaction of the stator a uniformly rotating field is produced. If the machine be assumed to be running at synchronous speed, the rotor will be stationary with regard to the field, and, therefore, an additional exciting winding supplied with continuous current can be placed on the rotor. By this means we come to the single-phase alternator as described in the paper.

The company with which I am associated recently built a 1,000-kw. generator of this type, and its operation has been entirely satisfactory. The squirrel-cage winding consists of copper bars carried in slots round the periphery of the rotor and short circuited at their ends by the brass rings used for retaining the exciting winding. By this means a very compact structure is obtained.

Before building this machine, some experiments were made with a slip-ring type induction motor, a description of which may be of interest. The stator of this motor had been wound with two conductors in parallel in the same slot, and for the purposes of this test these two windings on the stator were kept entirely separate. Fig. 1 shows the arrangement of the windings. Exciting current was supplied through the winding *A J B* and single-phase current taken from the two slip-rings of the rotor *G* and *H*. The other winding *D E F* of the stator was short-circuited through ammeters. The short-circuit rotor current produced for a given excitation with and without the winding *D E F* closed is shown in Fig. 2. In Fig. 3 is shown the single-phase short-circuit core loss with and without this winding short-circuited. The short-circuit current in winding *D E F* agreed very closely with the value expected, and consequently allowed the size of the squirrel-cage winding on the main alternator to be accurately determined.

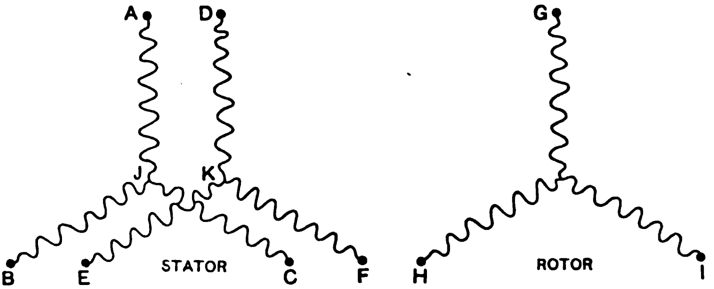


Fig.1

I agree with the author that this squirrel-cage winding forms a complete solution to the troubles experienced with single-phase turbo-generators. In addition to the reduction in the core loss, it will be noticed from Fig. 2 that the reactance has been reduced to a very great extent, so that a machine with this type of rotor—apart from the $I^2 R$ losses in the squirrel-cage winding, which are small—can be wound to give the same output three-phase or single-phase with approximately the same efficiency and regulation.

With regard to the second portion of the paper, the method of securing the stator coils, although apparently mechanically sound, appears to be open to two objections: first, the difficulty of ventilation, although perhaps this may not be serious; secondly, that the coils are set back a long way from the rotor. This location of the coils would tend to increase the self-induction of the latter considerably, as, although the medium surrounding the coils is only air, still the area of the magnetic path for a machine such as the one described by the author is very big, and it will probably be found that such a winding causes a considerably higher self-induction than a winding

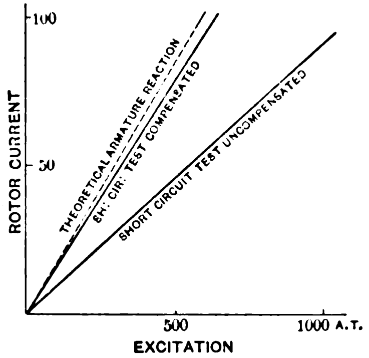


Fig. 2

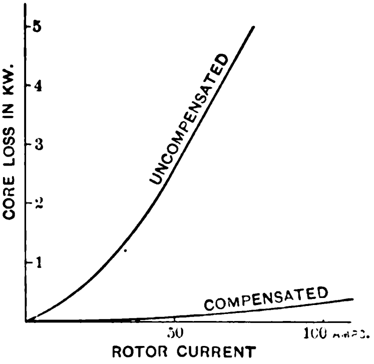


Fig. 3

which is brought out in the form of a barrel closely surrounding the end connections of the rotor.

Chas. P. Steinmetz: Since the question of single-phase alternators has come up, I desire to call attention to another way of accomplishing the same result of operating a single-phase load on a big alternator, without the objectionable features of the single-phase machine. This way is by using a polyphase alternator, that is, making the machine polyphase and storing the energy of the quadrature-phase.

The arrangement discussed by Mr. Waters is essentially a squirrel-cage winding on the field poles, or an equivalent thereto, in which currents are induced by the pulsation of the armature reaction, thereby giving the quadrature magnetomotive force, that is, the polyphase armature reaction. Theoretically, to effect this result completely would require a copper cross section in the squirrel-cage winding, or in the dampers, infinitely large compared with the armature section, as otherwise you get additional losses. If you give the dampers the same total section as the armature winding, to produce quadrature polarization, it means that you get the same (or, at any rate, not greatly differing) losses in the dampers as in the armature; in other words, you about double the $I^2 R$ loss.

This method, however, although it eliminates the pulsation of the field, and so also the losses in the field due to pulsation, does not eliminate pulsating strains on motor shaft and revolving machine, because the power is still pulsating; and where you come to very low frequencies, of fifteen to ten cycles, in very large machines, such as have been proposed, the enormous pulsation between zero and maximum power may become objectionable.

One way of eliminating this pulsation I will outline very briefly. Suppose you have a single-phase load of, say, thirty degrees lag, corresponding to average conditions of a single-phase railroad. Suppose you take a three-phase machine and put the load on one phase. Now, connect across another phase a reactive coil, to store the energy in the reactance. In the load the current lags thirty degrees behind the voltage, and the curve of power then is pulsating with double frequency, with a maximum 15 degrees behind that of the voltage. The electromotive force in the reactive coil is lagging behind the electromotive force on the load by 60 degrees, being the other phase. The current in the reactive coil lags 90 degrees behind its electromotive force, and the power of the reactive coil being pulsating (or rather alternating) with double frequency, has a maximum 45 degrees behind the voltage—a negative maximum, corresponding to power return, 45 degrees ahead of the voltage. Now, you see what happens. As the voltage on the reactive coil lags 60 degrees behind the load, the negative maximum of power in the reactive coil, 45 degrees ahead of its voltage, coincides with the power maximum of the load, which is 15 degrees behind its voltage. Superimposing then the alternating power of the reactive coil on the pulsating power of the load, you get constant power; that is, on the alternator by such a combination you can get constant uniform polyphase load with a single-phase external load, by a reactive coil displaced in phase by 60 degrees, storing energy, and returning it in the single-phase system.

If you look at the distribution of current, you will find that one generator coil carries only the load current, lagging 60 degrees behind the voltage of this coil, or Y voltage; one generator coil carries only the reactance current, also 60 degrees lagging behind the voltage of the coil; and the third coil carries the resultant of the load current, in phase with the coil, and the reactive current, lagging 120 degrees, so combining to a resultant current of 60 degrees lag. In other words, all three coils carry equal currents of equal phase displacements. In short, the machine becomes a perfect polyphase alternator, in armature reaction, in stresses, and in everything, but is storing power a part of the cycle, to return it into the single-phase system during the other part.

This arrangement may be used occasionally, and may become necessary, if we have to come to the use of very low frequencies.

W. L. Waters: Referring to Mr. Steinmetz's comments on my paper on single-phase generators: The system of balancing the load on a single-phase generator advocated by Mr. Steinmetz was, as a matter of fact, the first method which was suggested for overcoming troubles due to heating and loss of efficiency mentioned in my paper. Mr. Steinmetz's scheme is shown in the sketch. Phase *A* of a three-phase generator carries the single-phase load, this load being usually that of a single-phase traction system. Phase *B* carries a choke coil, which at the full voltage of the machine has a charging current equal to the single-phase rated load of the generator and a power factor of 87 per cent. As Mr. Steinmetz has shown, if the current in the choke coil *B* is equal to the current on the loaded phase *A*, and if the current in phase *A* has a lag of 30 deg. behind its electromotive force, then the currents in the three phases of the generator will be equal in magnitude and in phase, that is, the load on the generator will be a perfectly balanced three-phase load. That this method of balancing the load on a single-phase generator is only of theoretical interest is at once evident when we consider that the load on such a single-phase generator varies continually, both in magnitude and in power factor. If the choke coil *B* is adjusted so as to balance the generator when phase *A* carries full load and power factor of 87 per cent, then as soon as the load changes from this value and power factor, the machine becomes unbalanced. If the load falls off to a very low value, then the generator will be as badly unbalanced and will heat just as much as it would if running on full single-phase load without the choke coil. Thus we can see that even if we use such a choke coil, we would also require dampers on the pole faces when operating such a machine under the practical conditions of varying load. Such a choke coil can only be adjusted for one particular value of the current, and can only be adjusted for one power factor—otherwise two choke coils must be used. Thus we can see that the choke coil would have little value in practice. It also has numerous disadvantages. As it loads all the phases of the generator, it thus decreases the latter's efficiency and raises its temperature without increasing the output in any way. The cost of such a choke coil would be substantially equal to the cost of the generator, while the addition of dampers only increases the cost about 10 per cent. We have greater complication, more chance of breakdown, lower efficiency, and an arrangement which is only good for one particular value of the load and power factor. Thus I think it is not difficult to see why this choke-coil method was considered as being of only theoretical interest and as having no practical value compared to the simple, efficient, reliable, and universal method of applying heavy dampers to the field magnets, as described in my paper.

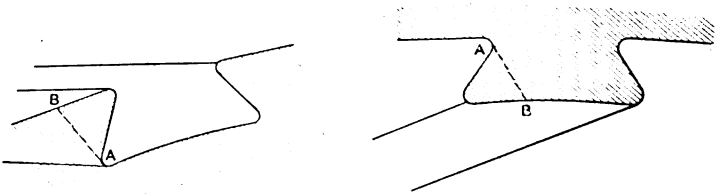


Fig.1

Mr. Behrend, begins by discussing the stresses in rotating disks and rings. The general statements made by him have been well known for the past twenty or thirty years, although there has not been any great necessity to apply them to electrical machinery, as high-speed units are only of comparatively recent date. A large number of approximate formulas have been worked out by various engineers for calculating the stresses in rotating disks and rings, most of them making various assumptions to simplify the problem. The most accurate of these formulas is the one given by Professor Ewing in his treatise on "Elasticity". Mr. Behrend, however, evidently figured his curves given in Fig. 7 from some formula which is only roughly approximate, as they differ 10 or 15 per cent from the stresses given by the most accurate formulas.

The generator described by Mr. Behrend is a 6500-kw., 300-rev. per min., 12,000-volt, 25-cycle, water-wheel driven alternator. The speed of this generator is comparatively high for a large water-wheel driven alternator, but is of very moderate speed compared to steam-turbine driven units, as there are a number of generators of this size operating to-day at 1500 rev. per min., that is, five times the speed of the generator described by Mr. Behrend. We can therefore see that the question of designing such a generator would not mean dealing with any new problems, but would simply mean choosing the design most suitable for this particular unit from a number of existing designs which have been thoroughly tried out. Mr. Behrend omits the electrical design entirely, merely giving us the performance of the machine; but he goes into the mechanical design in detail, and therefore I think we can assume that the latter is considered exceptionally good and that criticism is invited.

The construction adopted is a center disk of forged nickel steel without a hole in the center and with two forged nickel-steel rings, one on either side, and laminated poles dovetailed into the circumference. Before an opinion can be formed as to the suitability of this construction, an idea must be obtained as to the distribution of stresses throughout the field structure. As the stresses figured out considerably too high for conservative practice, the precaution was taken of having them checked before any opinion was formed. Considering first the tangential stresses in the disk, Mr. Behrend's curves give approximately the stresses in a disk of uniform thickness; but taking the disk used in this generator, as shown in Fig. 5, it will be seen that its thickness is by no means uniform. The side rings are registered into, and bolted to, the center disk, evidently in order that the center disk might strengthen the side rings as much as possible, and the result of this design is a disk virtually $32\frac{1}{2}$ in. wide at the circumference and thinned down to 4 in. at the center. We see from Mr. Behrend's curves that even in a disk of uniform thickness the maximum stress in the disk is at

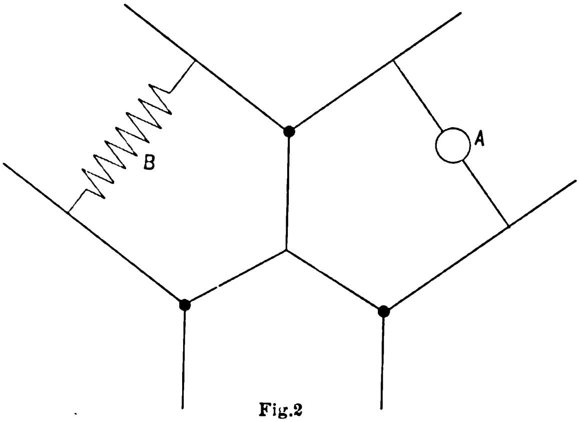


Fig.2

the center, and in this machine we have 4 inches in the center of the disk carrying the maximum stress due to the 32½-in. rim, and the poles. The stress at the center of the disk at 500 rev. per min. figures out about 35,000 lb. per square inch, which is more than double the stress in the rim. From the drawing we see that the shaft is registered into the disk at the center, and that in order to accomplish this registering the thickness of the disk has been reduced to about one-third, this thinning down being done by approximately right-angle variations in the thickness of the disk. The result of this design is that the stresses as estimated above are by no means uniformly distributed, and will probably run up considerably higher than the estimated 35,000 lb. per square inch around the sharp corners in the disk. It is moderately certain that the center of the disk is stressed in parts above the elastic limit, and that the metal stretches locally to allow other parts of the disk to assist in carrying the stress. The tangential stress in the side rings figures approximately 20,000 lb. per square inch.

The above estimated stresses are all figured at 500 rev. per min. and assume that there are no original shrinkage stresses in the disk and rings. Assuming that the disk and rings are good forgings, these shrinkage stresses should not be very great, but it is extremely improbable that there are not shrinkage strains of some sort in such large forgings. Test pieces show, of course, nothing in regard to shrinkage stresses in the material and merely show what the metal will do under the best conditions. The writer has known of castings in which shrinkage stresses of 25,000 lb. per square inch have remained even after annealing, and it is quite probable that the shrinkage stresses in these nickel-steel forgings are large. Assuming that there are such shrinkage stresses, it would easily be possible for the total hoop stress at some part of the disk to be greater than the ultimate strength of the metal. Thus it is decidedly doubtful whether the disk and rings are strong enough to stand the tangential stresses due to rotation at 500 rev. per min.

Considering next the stresses in the dovetails, the bending stresses tending to break the dovetail across the section *A B* can only be figured approximately. Making the most favorable possible assumptions, the stresses at 500 rev. per min. figure out about 45,000 lb. per square inch at the point *A*. But with a laminated pole and taper wedges, we cannot assume that the stress due to the centrifugal force of the pole is uniformly distributed along the length and width of the dovetail. Also, the overhanging end winding on the pole puts a greater stress on the corner *A* than it does on the center of the dovetail; and the fact that the corner *A* of the dovetail slot in the spider has a comparatively small radius again increases the stress, and may increase it to very high values. If these unfavorable features are neglected, the stress on the dovetail figures out as given above, but taking them into account we find that the stresses may run up to 150,000 lb. or 200,000 lb. per square inch at the same speed. Of course, the exact extent to which these unfavorable features increases the stresses cannot be decided, but it is very probable that the actual stress on the dovetails at 500 rev. per min. is above the ultimate strength of the material. All of this analysis of the stresses assumes, as in the case of the disk and rings, that there are no shrinkage stresses or local flaws in the forging. If there were such bad places, the complete wheel would not be safe even at a lower speed.

It would be difficult to bring the stresses in the dovetails down to a safe working limit; and their intensity in this machine merely confirms the general impression of engineers that the magnet construction in which complete individual poles are dovetailed into a spider cannot be built successfully in such large high-speed machines. The difficulty of accurately fitting the dovetails and the difficulty in estimating the exact stresses in them make it necessary to abandon them in favor of some construction which does not possess this disadvantage.

Considering everything, I think it is extremely probable that we would find that the disk and rings had been strained locally above the elastic limit even at the normal speed of 300 rev. per min., and if we were to run the machine at this speed and then shut down and gage the disk and rings all over we would find that there were evidences of local permanent distortion. Inasmuch as Mr. Behrend has so carefully pointed out that the maximum stresses in the disk are at the center, and since the thickness there could be increased five or six times without any change in overall dimensions, it hardly seems logical to thin down the disk to such a small section.

The design of the 6500-kw. alternator described in Mr. Behrend's paper can hardly be considered as a conservative one or one which it is desirable to duplicate, and I think Mr. Behrend is hardly justified in his statement that the design is "elegant and mechanically superior."

Chairman Armstrong: Mr. Behrend, do you wish to reply to Mr. Waters's remarks?

B. A. Behrend: I have nothing to say.

DISCUSSION ON "THE GENERAL EQUATIONS OF THE ELECTRIC CIRCUIT." ATLANTIC CITY, N. J., JULY 2, 1908

(Subject to final revision for the Transactions.)

Frederick Bedell: It is unnecessary to dwell upon the great value of the work of Dr. Steinmetz in this and other papers. It might be proper that this paper be presented at one convention and discussed at another, a year or two later. The increasing value of the work of Dr. Steinmetz impresses me more and more, and looking back over his writings of ten or twelve years ago we find that to-day many of them are of even greater value than when they were written.

There is one thing to be noted particularly in this paper, and that is that Dr. Steinmetz has continually called attention to the physical significance and practical meaning of his results. We do not always find this careful rounding out of a paper. Not long ago, in looking over a mathematical paper on a subject in which I was interested, I was much disappointed to find that the paper stopped abruptly, and I was unable to find out what was the author's conclusion.

On account of the nature of this paper of Dr. Steinmetz, we can make only a few casual comments, which bring out nothing new. When we impress an electric impulse upon a circuit, we have a wave going in each direction; each wave keeps going around and around the circuit, until it dies out, and each time it goes around the circuit it gives us one of those terms in the series, which are added up as Mr. Steinmetz has here done.

There is a physical feature to which attention might be called. We are most of us in the habit, when considering an ordinary alternating-current circuit, of thinking that the current in a series circuit is the same in all parts of the circuit, which is correct when there is no distributed capacity. In a circuit with distributed capacity, however, the current is not the same in all parts of the circuit; if we consider some point, P, in the circuit, the current may be going towards that point from both directions—a condition which we never have in a simple circuit without distributed capacity. This means that we are having electricity accumulated at that point. The point P, however, is not stationary, but travels along. We can think of this easier by analogy—by an hydraulic analogy. Considering first a pipe which is not flexible, an iron pipe, in which flows water which is not compressible; if we have a certain flow of water in one part of the pipe or circuit we have that same flow in all parts of the circuit. This construction illustrates the circuit without distributed capacity. Now let us consider, instead of a cast-iron pipe, a flexible rubber hose, and cause a series of impulses (as with a plunger) in the hose at one end; as a result of each impulse the hose will swell, and the swelling will travel along. Following the swelling there will be a contraction. Wherever there is a swelling, the water may be flowing from both directions towards the swelling;

and then it immediately flows away from the point and makes the hose contract. There is first a surplus and then a deficit of water (or electricity) and these are transmitted along the hose (or circuit).

Dr. Steinmetz called attention to the rates of decay, one with respect to time and the other with respect to distance. Suppose we have the impulses of different frequencies, or a complex wave which can be analyzed into the different component frequencies. These different frequencies, according to the equations of the paper, will be found to have different rates of decay; this is discussed in Chapters 12 and 13 of Bedell and Crehore's *Alternating Currents*. This means that if we have a complex wave impressed upon the circuit, the different components get to the receiving point at different times; one of them may get there a hundredth part of second later than another, so that when they combine again into the resultant wave the wave form at the receiving end of the circuit and the wave form at the sending end of the circuit will be different. In power transmission this is ordinarily insignificant. When applied to telephony this change in wave form becomes significant, and these equations explain the distortion of speech on telephone lines, a case which has already been worked out in detail by Dr. Pupin.

Dr. Steinmetz speaks of the reflected wave. I would like to ask him whether he considers there is any reflected wave in a uniform circuit, in which there are the positive waves going around the circuit in one direction, and the negative waves going around the circuit in the other direction.

Dugald C. Jackson: The equations which Dr. Steinmetz have deduced are finely developed, comprehensively organized offsprings of the equation which was devised by Lord Kelvin in the first days of transatlantic telegraphy to analyze the problem of transmission of electric signal pulses through ocean cables of negligible self-induction. That equation was fertilized and hybridized by Heaviside until it could be applied to the problem of the transmission of telephonic speech-currents in circuits of uniformly distributed resistance, self-induction and capacity. Dr. Steinmetz has taken a third great and important step in developing equations which are applicable to complete circuits composed of sections of diverse characters and which also take adequate account of the terminal conditions or apparatus. The paper deals with the offspring of old friends in the electrical science, but the offspring are much more comprehensive and fully developed than the parents.

It has been usual to refer to a vibrating wire as a mechanical analogue of an electric circuit in either forced or natural electric oscillations,—that is, either when it is required to act under imposed pulsations or when stimulated into action and then left to carry out its own sweet will. A uniform wire however does not afford an illustration of the usual electric circuit of practice.

An electric circuit is ordinarily made up of sections of diverse electrical characters. Some of these sections may be long and some may be short, but they are almost inevitably found in the circuits of practice and their diversity of character robs the uniform wire of its usefulness as an analogue. We must therefore abandon the uniform wire for our analogue and take up a wire composed of sections of diverse character welded end to end. Sections of small resistance may be thought of as vibrating in air, others of higher resistance must be thought of as surrounded by molasses or other liquid of a density to correspond at each section with the desired resistance. In certain sections may be injected a large *mass* or *inertia* to represent high self-induction, and the elasticity from section to section must be adjusted to correspond with the desired electrostatic capacity. When this wire made up of diverse sections of appropriate characters is attached to abutments of suitably adjusted elasticity and inertia it affords a true analogue of electric circuits of practice; but the analogue has become too complex to be illuminating. I have not found it possible to foresee the reactions that will occur in each section when a disturbance of particular character is put on such a wire by external means. Moreover, although uniform vibrating wires or plates, or loaded wires giving the semblance of uniform wires, have been prolifically treated in mathematical works, I have never observed a treatment adequate to predetermine the reactions in any wire of diverse sections. Dr. Steinmetz has now come to us with the formula for the electric circuit itself, which not only makes the analogue of less need but also probably at the same time gives the solution of the analogue.

The paper is reassuring and encouraging to the man who has only looked at it hastily, in that the simpler results set forth in it correspond with the phenomena that we know actually occur. For instance, as far as the telephone circuit is concerned, the effects of "loading" that Dr. Steinmetz sets down categorically as deductions from his equations, are those that are known to occur in the telephone circuit. Thus, it is known that leakage up to a certain degree and under certain conditions assists transmission of speech in a telephone circuit or the transmission of signals through an ocean cable, but that an excess of leakage beyond a point fixed by other conditions makes transmission worse. It is also well known that "loading" a telephone circuit under certain conditions materially improves the transmission of speech, but a line loaded to give admirable transmission with low leakage may afford poorer transmission than an unloaded line if the leakage becomes large. For instance, a particular loaded aerial open-wire telephone line may be good to talk over in clear weather, but let the weather get bad and the leakage become large and the loaded line is frightful to talk over; whereas 100 miles, or 150 miles of loaded underground line gives admirable transmission in all sorts of weather, because the leakage and other constants of such a line do not vary with the weather. That is the deduction Dr. Steinmetz draws from his equations. He doubtless knew these facts in advance, but they are demonstrated in his equations; and it is assuring to find that the equations do tell the truth in these simple matters, as this truthfulness supports a reliance upon their accuracy in more complex matters.

As an illustration of the fact that this paper carries us beyond what has been heretofore our frontier of knowledge, I will point out that the equations apparently enable us to understand the effects of terminal conditions on the action of circuits. As far as telephone analysis has heretofore gone, it has almost solely related to uniform circuits or to loaded circuits which are brought to the condition of substantially uniform circuits. The equations heretofore have not been able to cope successfully with the difficulties of the complete circuit including the complexities of terminal conditions, and the conditions of the telephone receiver and transmitter have been omitted from mathematical consideration or merely approximated. I believe that great advances in intercommunication by the telephone and telegraph are yet to come about from improvements of terminal conditions, and not so much from further improvements in the knowledge of line conditions. These equations of Dr. Steinmetz apparently lay the foundation for study of terminal conditions that may result in the improvements to which I refer.

I am now going to diverge for a moment and go back to a point to which I referred on Tuesday; and that is the tremendous increase in output of what is often called " pure " science which now accompanies the advance of engineering. This paper illustrates the point. Formerly, engineers were followers of the men of scientific research, and the men of scientific research looked with some disdain upon men of the engineering industries. At the present time the engineers have caught up with and absorbed pretty much all of the accumulated output of the pure scientists, and they quickly absorb the current output as fast as it comes along. To keep the output in pure science (especially in physics and chemistry) abreast with the advance of the engineering industries, the engineers themselves have been forced to enter the field of pure research and their product must be recognized as unexcelled by that of the so-called pure scientists.

Dr. Steinmetz has set out in his paper a number of pronounced facts, and some of them illustrate how truth, when it is presented to one plainly, seems so common-sense and persuasive as to be almost axiomatic. For instance, Dr. Steinmetz calls attention to the fact that " The oscillation of a circuit, which is open at one end, grounded at the other end, is a quarter-wave oscillation, which can contain only the odd harmonics of the fundamental wave of oscillation." He further says " The oscillation of a circuit which is open at both ends, or grounded at both ends, is a half-wave oscillation, and a half-wave oscillation can also contain the even harmonics of the fundamental wave of oscillation, and so also the constant term, for $n = 0$ in (78)." That is to say, one can get a very erratic wave (compared with a sine alternating wave) when one sets up oscillations, and oscillatory waves need not be always of symmetrical half-pulses. The view that is commonly taught in the classroom explains the facts only partially. In another place there is stated a very interesting and very striking thing. After having studied some familiar equations we find the statement that " the wave shape of the oscillation remains unchanged during the decay of the oscillation." Then another very striking thing is found, where it is pointed out that " the wave does not die out in each section at the rate as given by the power consumed in this section, or in other words, power transfer occurs from section to section, during the oscillation of a complex circuit." I do not think that this had come to my mind before it was pointed out to me by Dr. Steinmetz. It seems a fact of great significance.

There are a number of other similar, clear-cut, categorical statements in the paper, which make it interesting to read even to one who does not undertake to go through the equations one by one for the purpose of getting more in the way of facts out of them.

Finally, I wish to congratulate Dr. Steinmetz upon the directness of the attack with which this paper goes at its object. The studies that have heretofore been made on this subject have been more or less of a roundabout siege. The direct assault, when it can be made, though sometimes imposing greater hardship on the attacking party, ordinarily brings greater results than a siege; or, at least it brings, as a rule, results that are more immediately and broadly useful. Dr. Steinmetz has been able to make successfully a direct attack upon the characteristics of a circuit that varies in character throughout its length. His processes are as novel as they are interesting, and I wish again to congratulate the Institute on receiving this demonstration of the great results that can follow a direct attack by mathematical analysis.

H. L. Wallau: I would like to ask Dr. Steinmetz one question. He mentions a voltage transformation at the transition point. If I am not mistaken he told us that at that transition point there could be but one frequency, the same on each side of the point, because the end of each section being the same point as the beginning of the next, the frequency was the same. If a voltage transformation occurs, can there be two voltages at the transition point? How does the transformation take place?

Chas. P. Steinmetz: As regards the reflected wave in a uniform circuit, the question Dr. Bedell brought up; if you had a perfectly uniform circuit without terminal points—a closed circuit—we could imagine a wave without reflected wave, going around and around, provided we could produce such a wave. I cannot, however, at present see any possibility of producing such a wave, since any impulse or any action on the closed circuit would naturally produce two waves running in opposite directions from the starting point, and then either of these could be considered as the main wave, the other as the reflected wave. But in general when dealing with uniform circuits we have terminal points, because although the uniform circuit with terminal points, such as a line open at both ends, is not of very great practical importance, a perfectly uniform circuit without terminal points —that is, the line closed on itself at both ends—does not appear feasible from a practical standpoint.

As to the questions asked by Mr. Thomas, I think there is a misunderstanding. If we consider a circuit, with the generator on one end, the load on the other end, the main wave decreases from the generator toward the load, while the reflected wave decreases from the load toward the generator. That is, looking at the waves in the same direction of the circuit, from the generator toward the load, the one wave decreases, the other increases with the distance. However, in treating of waves increasing or decreasing with the distance, I always consider them in the direction of propagation, which in the reflected wave is opposite to that of the main wave.

Considered in the direction of propagation, the character of the reflected wave thus is always the same as that of the main wave, either increasing with the distance or decreasing with the distance. The two component waves of the general equations, that which decreases with the distance, and that which increases with the distance, thus can not be a main wave and its reflected wave, but each of the two component waves comprises a main wave and its reflected wave.

Regarding the transformation of current and voltage at a transition point, this is a very interesting subject, deserving a far more extended discussion than was feasible in the paper. On the two sides of the transition point the resultant currents must be equal, and so also must be the resultant voltages. These however are the resultant of several waves, the main waves and the reflected waves, and the transformation ratio applies to the individual waves. Thus, at one side of the transition point the main wave and the reflected wave differ from those on the other side of the transition point by a constant factor, the transformation ratio, but at the same time the phase-angle on one side differs from that on the other side in such a manner that the resultant of main and reflected waves is the same at both sides of the transition point. As seen, this feature connects the phase-angles on the two sides of the transition point (hence the law of refraction) with the transformation ratio. For instance, if on one side the main wave and the reflected wave are much greater than on the other side, they are more nearly in opposition on the former side than on the latter, and therefore give the same resultant. However, as the phase-angle changes from point to point in the circuit, at some point, distant from the transition point, the main wave and the reflected wave are in phase with each other. The resultant is then their sum, and higher on the side where the individual waves are higher, Hence the maximum values, of the wave-crests in the circuits on both sides of the transition point, have to each other the transformation ratio of the transition point (multiplied by the decrement of the circuit between transition point and wave crest). Thus, when transforming up at a transition point, at this point the voltage remains the same, but the higher voltage appears at the next wave-crest.

W. S. Franklin (by letter): I have found Mr. Steinmetz's paper on the General Equations of the Electric Circuit to be very instructive, and what I wish to say in discussing the paper relates chiefly to a method for discussing electric-wave motion which is due to Heaviside. Some time ago, in reading a treatise on optics by one of our leading specialists on that subject, I came across this statement: " To prove that any phenomenon is due to wave motion, it is sufficient to show (1) that it is periodic, and (2) that it is propagated with a finite velocity ", and immediately there came into my mind the idea of bullets from a Gatling gun, which are periodic and which are propagated with a finite velocity. The fact of the matter is that the idea of periodicity has been too much used in the discussion of wave motion. The wave pulse involves all of the important actions of wave motion, except that action which serves as a basis for the theory of the dispersion of light,* and the physics of wave motion may be developed in the simplest possible manner by considering the behavior of wave pulses; for it is certainly true, as Heaviside says, that the physics of wave motion is presented in its simplest aspects in a wave pulse, whereas the mathematical formulation of the wave pulse is extremely complicated. On the other hand, the physics of the wave train (a periodic succession of similar waves) is extremely complicated, and its mathematical formulation is fairly simple.

I have recently been engaged in the preparation of a paper on electric-wave motion on transmission lines and on the electric oscillation of transmission lines, and a few abstracts from this paper will serve to illustrate the point of view of Heaviside.

Fig. 1 shows a transmission line, initially open at both ends, one line being positively charged, the other negatively charged—both uniformly. The end of the line is suddenly short-circuited, a current is suddenly established at the end of the line, the charges on the wires disappear, and a *wave sheet* W travels in the direction of the arrow V, wiping out the electric field and charges completely and establishing the magnetic field and curaway from the reader. When the wave sheet W reaches the rent as it travels along. The lines of force of the magnetic field are represented by the dots and the magnetic field is directed open end of the line, the energy, which initially was electric, has been wholly converted into magnetic energy; the current, which has the same value over the whole line, is then suddenly reduced to zero at the open end, and, in being reduced to zero, it builds up a reversed charge and a reversed electric field at the extreme end of the line; and a wave sheet travels in a reversed direction along the line, wiping out magnetic field and electric current and laying down the reversed electric field and charge. When this wave sheet reaches the short-circuited end of the line, the line is uniformly charged (with zero current everywhere). The charge then suddenly disappears at the short-circuited end of the line, establishing a reversed current and a reversed magnetic field both of which are established by a wave sheet which travels towards the open end of the line. When this wave sheet reaches the open end of the line, the reversed current is suddenly reduced to zero at the open end, a wave sheet travels back to the short-circuited end and re-established the initial charge and initial electric field, so that when this wave sheet has reached the short-circuited end of the line, the entire system is in its initial condition and the line has performed one complete oscillation. Line resistance is ignored in this discussion.

---

* The simple wave trains constituting the parts of the solar spectrum which is formed by a prism are produced by the prism and do not exist *as such* in the complex waves which enter the prism from the sun.

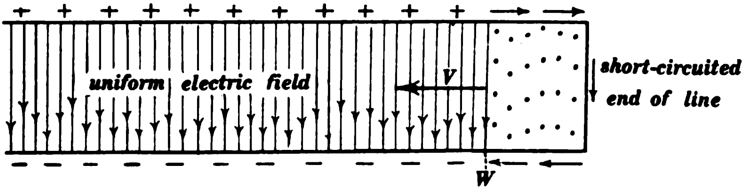


Fig. 1

Fig. 2A represents a generator delivering current over a line of negligible resistance to a receiver of negligible resistance (the system is short-circuited). The receiver end of the line is suddenly opened, the short-circuited current is suddenly reduced to zero at the opened end, and, in being reduced to zero, builds up an electric field between the lines and charges the lines, as shown in Fig. 2B (voltage assumed not to rise to a sufficiently large value to break across from line to line). The short-circuit current (and the magnetic field which corresponds to it) is wiped out by a wave sheet W'', and the electric field and charges are laid down by this wave sheet which travels towards the generator. A complete cycle of oscillation may easily be traced very much as in the case of Fig. 1.

A battery is suddenly connected to one end of a transmission line as shown in Fig. 3A, the other end of the transmission line being open. A wave sheet W' shoots out from the battery end of the line establishing a current in the line and magnetic field between the lines, and also establishing electric charges on the lines and an electric field between them, as shown. When the wave sheet W' of Fig. 3A reaches the open end of the line, the current in the line is suddenly reduced to zero, and in being reduced to zero builds up a doubled charge and doubled electric field as shown in Fig. 3B, this doubled charge and doubled electric field being established by a wave sheet W'' which travels back towards the battery end of the line. A complete oscillation of the line may easily be traced in this case, as in the case represented in Fig. 1.

A very interesting case is the establishment of current in a long transmission line, short-circuited at the far end, when a battery is connected to the near end, resistance being neglected. A wave sheet shoots out from the battery as represented in Fig. 3A ($I = E\sqrt{\frac{C}{L}}$, where L and C are line inductance and line capacity per unit of length, respectively, E is the voltage of the battery, and I is the current in the line behind the wave sheet). When this wave sheet reaches the short-circuited end of the line, the electric field between the wires drops to zero at the extreme end and the current rises to $2\,I$, and this doubled current and zero voltage is established over the whole line by a wave sheet which travels back towards the battery end. When this wave sheet reaches the battery end, the whole action is repeated *on top of the existing short-circuit current* $2\,I$. That is to say, a current $3\,I$ and battery voltage E are established over the whole line by a wave sheet which shoots out from the bat-

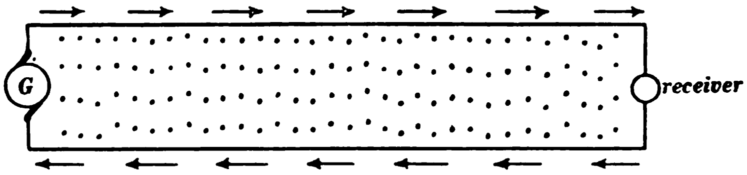


FIG. 2A

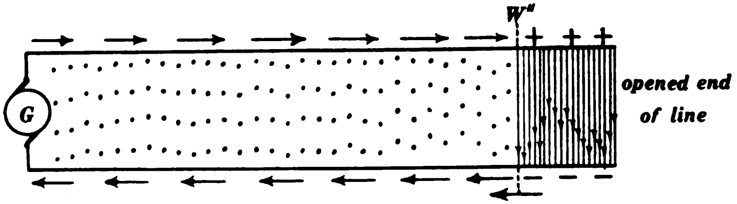


FIG. 2B

tery, and when this wave sheet reaches the short-circuited end of the line, a current 4 *I* and zero voltage are established over the whole line by a wave sheet which travels back towards the battery end. And so on. The action is precisely analogous to the surging motion of a frictionless railroad train which gets under way under a constant locomotive draw-bar pull. At the beginning, the constant pull establishes a certain velocity *I* which travels backward until it reaches the caboose; then the stretched coupling springs jerk the caboose forward and a velocity 2 *I* is established which travels forward until the whole train is moving at velocity 2 *I* with coupling springs entirely freed from stress; and then this process is repeated on top of the existing velocity 2 *I*.

A stretched string, *A B*, Fig. 4A, is pulled to one side at the point *P*; the water at one end of a canal *C D* is held uniformly elevated and the water at the other end uniformly depressed by a gate at the center of the canal; a transmission line, *E F*, open at both ends and broken at the middle, has two batteries connected as shown, thus producing an upward electric field between the wires at one end of the line and a downward electric field between the wires at the other end of the line. The three diagrams on Fig. 4B represent the state of affairs when the initial disturbances which are represented in Fig. 4A are released. When the point *P* is released the middle portion of the string gets into motion at a uniform velocity and is entirely relieved from the stretch due to the distortion, which is represented in *A B*, Fig. 4A. The middle portion of the water in the canal immediately settles to its normal level and is set in uniform motion as represented in the diagram *C′ D′*. When the switches

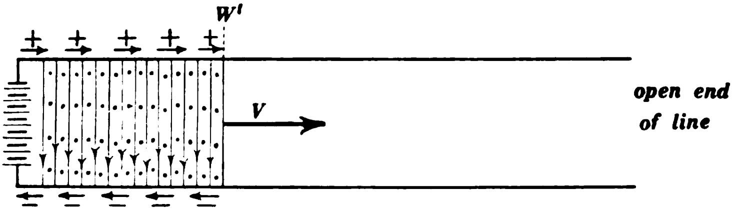


FIG. 3A

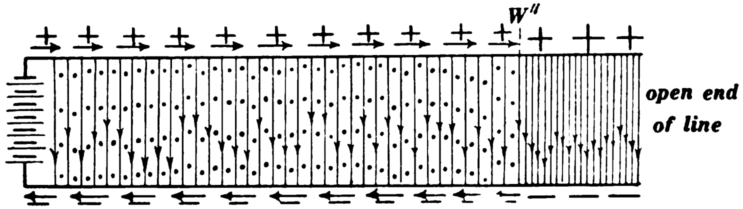


FIG. 3B

in $E\,F$, Fig. 4A, are closed, the charge near the middle of the line disappears, and a uniform current (and magnetic field) is established as shown in the diagram $E'\,F'$. A complete cycle of oscillation may easily be followed in each case.

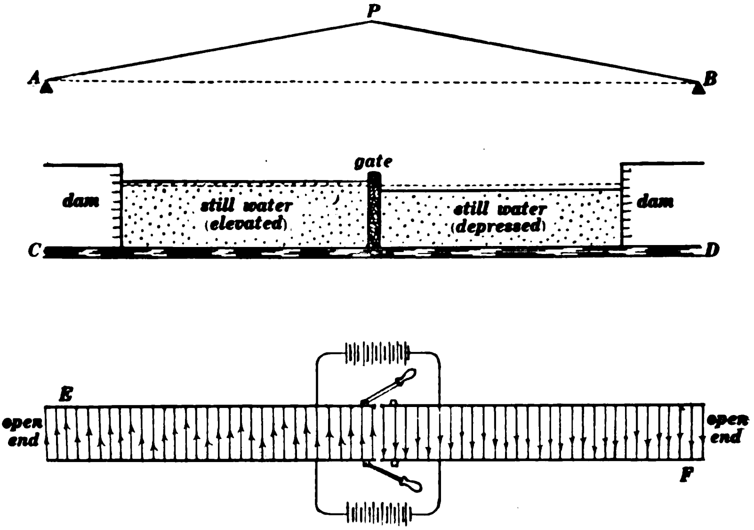


FIG. 4A

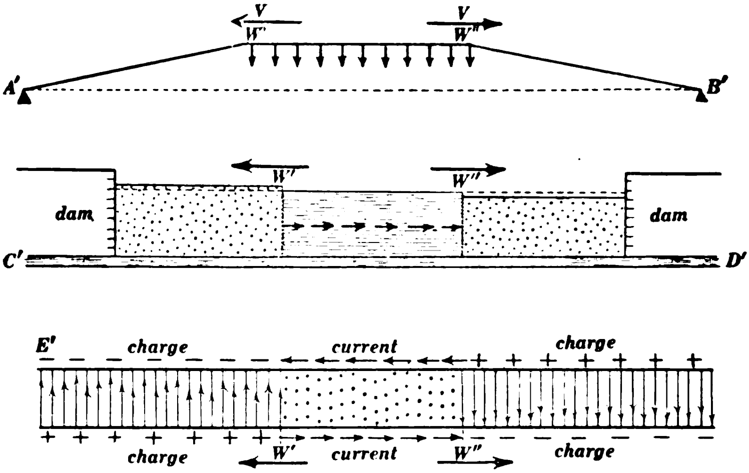


FIG. 4B

The paper which I am preparing on electric-wave motion is devoted (1) to the establishment of clear ideas of the physical action which is involved in the electromagnetic wave; (2) to the discussion of a great variety of special cases; and (3) to the modification of the results so reached by the effects of line resistance and line leakage. I wish to call attention to the extremely simple discussion of electromagnetic waves which is to be found in the first volume of Heaviside's *Electromagnetic Theory*, pages 306 to 455, in which the fundamental ideas of electric-wave motion are developed on the basis of negligible attenuation (due to resistance of line and leakage between wires), and the effects of line resistance and line leakage are then described in extremely simple terms as a diffusion phenomenon modifying the results that are arrived at in the first instance. I know of no discussion of electric waves more edifying than this of Heaviside's. It would be misleading, however, if I did not mention the fact that throughout the second volume of Heaviside's *Electromagnetic Theory* the mathematical formulation is based, as it must be, upon exponential and periodic functions very much as Dr. Steinmetz has developed it, and that the mathematical formulation of the wave pulse is accomplished by the aid of Fourier's integrals. Such methods must be used if one is to arrive at numerical results, but I think that a clear conception of any physical phenomenon is a thing without which no one can make use of numerical results, or even be led to seek for them.

DISCUSSION ON "AN IMPERFECTION IN THE USUAL STATEMENTS OF THE FUNDAMENTAL LAW OF ELECTROMAGNETIC INDUCTION." ATLANTIC CITY, N. J., JULY 2, 1908

(*Subject to final revision for the Transactions.*)

George A. Campbell (by letter): The very simplicity of the facts and principles which Maxwell stated is, apparently, the reason for their being overlooked in the present discussion. The points requiring restatement seem to be the following:

1. Electric currents and magnetic lines of force are both closed. This statement is true irrespective of whether the electric conductors and magnetic cores are open or closed. The current is determined by the integral electromotive force around the circuit, and thus any experimental measurement of the current gives us the total and not the localized electromotive force. An exact statement of fact must then relate only to the integral values for the entire closed circuit; accordingly, Maxwell's statement (Vol. II, paragraph 541) is in terms of these integral qualities:

"The total electromotive force acting round a circuit at any instant is measured by the rate of decrease of the number of lines of magnetic force which pass through it."

This is the fundamental statement of fact, as distinct from theory, in electromagnetic induction.

2. As the current and the lines of force are invariably closed, it follows as a mathematical necessity that the rate of cutting of lines of force by the circuit is equal to the rate of change in the number of lines of force through the circuit. Maxwell expresses this (Vol. II, paragraph 541) as follows:

"If, therefore, the number of lines which pass through a conducting circuit is made to vary, it can only be by the circuit moving across the lines of force, or else by the lines of force moving across the circuit. In either case, a current is generated in the circuit."

The ordinary "cutting of lines of force" statement is thus a derived law and involves something more than the experimental facts. This addition may be merely the mathematical theorem that for any closed circuit the integral result of the "cutting" statement is the same as that of the "flux" statement; or it may also include, consciously or unconsciously, the hypothesis that the induced electromotive force is physically and locally associated with the cutting of the induction. However natural it may have been for Faraday to localize the induction at the point where there was cutting of the lines of force, it is evident that this was theory and not experiment, for the experimental facts may be accounted for on the hypothesis of action at a distance. If Faraday's theory rather than Faraday's experiments is made the starting point, then, of course, "cutting of lines of force" is fundamental and the flux statement becomes the derived law.

3. The law of induction applies to circuits in non-conductors

as well as to circuits in conductors. One of the most important applications of the law is to the free ether, where no materials are present. Mr. Hering's restriction to conductors would therefore be perfectly arbitrary and extremely inconvenient. Where the conductor is not closed the circuit is always completed through the dielectric. The induction in the dielectric must always be borne in mind.

4. It is self-evident that the fundamental statement of the law of induction applies to a linear circuit and that it can be extended to a circuit having a finite cross section only after the system has been resolved into infinitesimal filaments. This principle is an elementary one in applied theory, but its recognition eliminates all difficulty in the application of the flux statement to Mr. Hering's "crucial" experiment. Thus the sketch shows the springs in the process of sliding over the magnet which is resolved into a network of conducting filaments. As it is found to be immaterial how this resolution is made in the present case, a simple illustrative network is all that is attempted in the sketch. In the experiment, all of the induction passes through the iron and none of it through circuit 1. Motion of the springs does not change the number of lines of force threading circuit 1 or circuit 2 or any of the remaining 17 circuits. Therefore, the integral electromotive force around each circuit is zero; and no currents can flow; hence the experimental result.

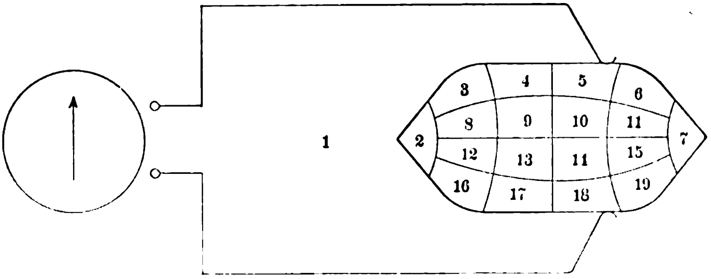


FIG. 1

5. When it is possible to state a law in more than one way it is ordinarily true that the application of the law to different problems will be facilitated by the choice of different forms of the law, and that this is the case with the law of induction is not surprising or significant. As Mr. Hering happened on a unipolar experiment he found the cutting statement more convenient, as have others before. Had he happened upon an experiment involving toroidal coils or slotted armatures he would presumably have advocated the flux statement.

6. Mr. Hering's new machine is actually a unipolar dynamo. Faraday in his machines, preferred to make both the cutting of

lines of force and the sliding of contacts perfectly uniform; this condition seems to be the ideal one and it is now being found to be commercial. Obviously this particular arrangement is not necessary. This is Mr. Hering's machine, while the induction cut by each spring is (on the whole) in one direction throughout the motion, the cutting and the sliding of contacts are made intermittent and alternate with each other. The expectation aroused at the beginning of Mr. Hering's paper that the limitations of the magnetic induction machine were about to be extended meets with disappointment. It still remains true that for a direct-current machine magnetic induction alone is not sufficient; sliding contacts, a commutator, a variable resistance or some other auxiliary device is necessary.

To summarize: The " flux " law is a literal statement of the observed facts of electromagnetic induction and enables the results to be predicted in any case whatsoever. The unipolar induction experiment described by Mr. Hering presents no exception to this rule and throws no new light upon the subject. The "cutting of lines of force" statement may be regarded either as a mathematical substitute for the " flux " statement, or as a theory localizing the observed action. Both statements of the law are useful in practice.

Tracy D. Waring (by letter): Any great generalization when concisely worded is a likely cause of misapprehension. The novel and ingenious experiment by which Mr. Hering links and unlinks magnetic flux into and out of an electrically closed conducting circuit without producing any inductive effect should go far towards removing a prevalent misunderstanding or misinterpretation of the law which for brevity we may term the Linkage Law of electromagnetic induction.

In considering some of the questions raised by Mr. Hering, it would seem appropriate to call to mind the physical conceptions as to the nature of electromagnetic induction from the point of view of electromagnetic theory.

In any circuit undergoing electromagnetic induction, the electromotive force produced in that circuit is due to, or rather owes its existence to, the electric intensity[1] developed at some or all of the points of the circuit. The seat of the electric intensity (electromagnetically produced) can only be at that place in a medium where the magnetic field is in some way changing relatively to the medium, so we may perhaps describe electromagnetic induction thus: Consider any point of a medium in which a magnetic field is sustained; then electromagnetic induction, if it exists there, may be described as the production of an electric intensity, at the point considered, by a change in the magnetic field at that point.

If this statement be true, what shall we understand by a *change in a magnetic field at a point*? How is such a change to be specified and by what physical conception may we picture it?

---

[1] Also variously termed electromotive intensity, electric force, and intensity of electric field.

An adequate answer to these questions, if such be possible, would involve a complete physical theory of the ether and matter, a problem so profound and vast that the considerations here presented have by comparison but slight significance. These considerations are ventured, however, as laying stress on a certain aspect of the common conceptions relating to electromagnetic induction.

Taking the case of a magnetic field in an isotropic medium having unit permeability (that is, a medium in which the magnetic intensity and the magnetic induction are numerically identical), how shall we describe a change of the magnetic state at a point in such a medium and the related electric state or electric field accompanying the change of magnetic field? The magnetic field has at every point intensity and direction, either or both of which may change. A change of magnetic intensity at the point will suffice to produce an electric intensity there, the directions of the electric and the magnetic intensities being so related as to be at right angles to each other. But that is not all. Both the magnetic intensity and its direction may remain constant and yet some change in the magnetic field may take place, at a point in the medium, that will produce an electric intensity there. Relative motion between the magnetic field and the medium will do this. Such relative motion then also represents a change in the magnetic field at a point.

But how shall we picture such motion? Consider any point or points of a medium in which a *uniform* magnetic field is sustained. Conceive, if you can, a relative translational motion of the *uniform* field with respect to the point or points fixed in the medium. The magnetic intensity and its direction are everywhere constant, and no instrument fixed in the medium and indicating only intensity and direction would give any indication that the field was moving; yet we can hardly doubt that something does, or may, move relatively to the medium and that the medium responds by having an electric intensity produced in it (unless the line of motion happen to coincide with the direction of the magnetic intensity).

By what physical conception can we make such relative motion have a physical meaning? Perhaps we may put it as follows: Intensity and its direction, as we measure them, do not fully specify a magnetic field at a point. It is not to be expected that so simple an expression could give more than the faintest clue to the physical state we call magnetic, for even a so-called uniform field is not really uniform for very minute dimensions—let us say, for instance, for dimensions of atomic size or perhaps much smaller. If we could only see fine enough we would see that a so-called uniform field possesses some sort of polarized structure, magnetic filaments of some sort all running the same way and perhaps uniformly spaced.

And so we appear compelled to fall back on a conception of lines of force or tubes of induction having some sort of a real physical existence, if the relative motion between a uniform field and the medium in which it is sustained is to have physical significance.

Take a simple concrete example, say a uniformly magnetized permanent magnet shaped something like the letter C with pole faces broad and flat and not very far apart (see Fig. 1). Let the surrounding medium be a dielectric, insulating oil for instance, which we shall suppose remains quiescent around the fixed point, *P*.

The field near the center of the pole faces is practically uniform. Nearer the edges its intensity is weaker and changes in inclination, that is, in direction. Now what happens as the magnet moves forward, relative to the point *P* fixed in the oil, and in the direction indicated by the arrow? It is not difficult to conceive of the magnetic state being created in front of the poles as the magnet advances, and the same kind of state disappearing or being destroyed behind them, while in that part where the field is uniform the magnetic state is constant and apparently does not in any way change as the upper pole face passes over and the lower one under it. But consider the matter more closely. Imagine a minute but intelligent being, stationed at *P*, equipped with an instrument suitable for indicating to him the intensity and direction of magnetic field. Watching his instrument as the magnet begins to approach him, he sees the magnetic intensity growing stronger and stronger and ever changing in direction (inclination), but presently it reaches a maximum and remains constant in magnitude and direction. He is then in that part of the field which we call uniform. But is that state, which we call magnetic, really at rest about him? Could he perhaps not see, with a wonderful imaginary eye, the magnetic filaments or magnetic whirls or lines of stress or flow or whatever they are—could he not see them file past him as the pole faces move above and below

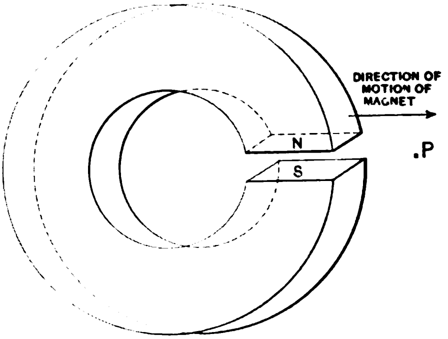


Fig.1

him, or, as a last resort, could he not devise an instrument that would indicate an electric intensity in the field about him?

Considerations similar to these arise in considering the rotation of a magnetic field about a line of force as axis which happens to be also an axis of symmetry for the field. For instance, Mr. Hering raises the question: Does the magnetic field of a round, uniformly magnetized bar magnet rotate with the magnet if the magnet be made to rotate about its axis by mechanical means? Here for any given point in the field the magnetic intensity is constant in direction and magnitude whether the field rotate or remain stationary?[2]

Sir Oliver Lodge believes that the field does rotate with the magnet, or at least he says: "If a magnet were spun on its axis rapidly by mechanical means, there is very little doubt but that it would act on charged bodies in its neighborhood, tending to make them move radially either to or from it. This, however, is an experiment that ought to be tried; and the easiest way of trying it would be to suspend a sort of electrometer needle, electrified positive at one end and negative at the other, near the spinning magnet, and to look for a trance of deflection—to be reversed when the spin is reversed. A magnet of varying strength might be easier to try than a spinning one."[3] Mr. Hering suggested the use of a single wire and a condenser for an experiment of a similar character.[4]

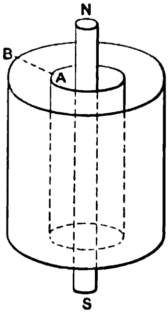


Fig.2

To fix our ideas, imagine the arrangement indicated in Fig. 2, which represents a bar magnet capable of rotating around its axis and encircled by two concentric and coaxial cylindrical conducting surfaces. The two surfaces, which we may look upon as the two plates of a cylindrical condenser, are fixed in space, while the magnet may be made to rotate by some mechanical means not indicated in the figure.

---

[2] We are of course not considering enormous hypothetical peripheral speeds, such as would be comparable with the rate of propagation of magnetic disturbances.

[3] Modern Views of Electricity, Section 73, 1907 edition, by Oliver Lodge. Also see Lodge, *Phil. Mag.*, June 1889, page 469.

[4] A New Factor in Induction; the "Loop" *versus* the "Cutting Lines of Force Law", by Carl Hering, *Electrical World*, March 14, 1908.

Now assume the magnet to be rotating around its axis at a high speed and then place a conductor, say a piece of wire, across from *A* to *B*. If it be true that the field rotates with the magnet, then such of the flux as passes between the cylinders will cut the wire and the cylinders will become charged electrically. Their electrical condition could be investigated after first removing the wire and then allowing the magnet to come to rest.

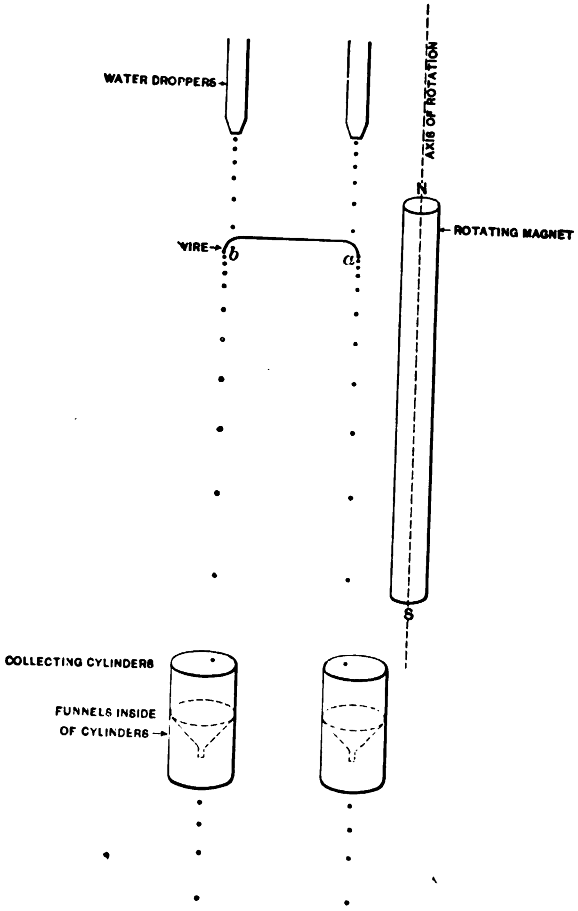


Fig.3

The experiment might perhaps be modified so as to get cumulative results by means of water-drop collectors as in Fig. 3. With this arrangement the magnetic flux of the rotating field cuts the wire, establishing an electromotive force between the ends *a* and *b*, in consequence of which the water-drops at the extremities of the conductor take on opposite electrical charges. The charges are carried off by the water-drops, and the latter in turn give up their charges to the collecting cylinders which should become more and more heavily charged.

Of these suggested experiments that proposed by Lodge is perhaps of the greater theoretical interest, as it could be performed in some suitable dielectric without perhaps using any conducting material in the field, and is in line with the experiment so successfully carried out by Dr. H. A. Wilson in which he measured the electric displacement in a dielectric resulting from its motion in a magnetic field.[5]

Carl Hering (by letter): Concerning Dr. Steinmetz's remarks. I am greatly pleased to see that he agrees with me on the main points. The statement of the general law of electromagnetic induction which he gives is probably the first statement which has ever been published of a form of the law which is really universal, so far as we know now, and I hope that in the future it will be copied into text-books freely; I know of no case, no matter how complicated, in which the student would be misled into getting wrong conclusions or even only doubtful conclusions, when applying this new statement of the law. The only comment I have to make about it is that, to be quite accurate, it should be preceded by a statement that it applies only to elemental conductors, that is, to conductors the cross-section of which is negligibly small; when the cross-section is relatively large, some further limitations would have to be introduced into the law to make it strictly correct and these limitations would complicate it.

What Dr. Steinmetz says concerning the form of induction in unipolar machines, was, of course, well known to me, but the usual unipolar machine does not come directly under Maxwell's law as there is no definite limited loop in which the enclosed flux increases or diminishes. Hence the induction in unipolar machines has, for many years, not been considered a direct contradiction of Maxwell's law, or of the law of linkages. In my experiment, however, the conditions are such that Maxwell's law can be applied directly, there being a very well-defined permanently closed loop and a well-defined increase and decrease of flux enclosed by that loop. It therefore contradicts Maxwell's law directly, while the induction in unipolar machines does not do so, directly. I am pleased that Dr. Steinmetz agrees with me that Maxwell's and Thomson's statement of the law are not universal, but refer only to special cases. If Maxwell's law applies only to " conditions of continuity of conductor and continuity of motion " as Dr. Steinmetz states it, this limiting condition ought always to accompany the statement of Maxwell's law; but this is not the case in most text-books; and the student should not be left to find out these limiting conditions himself.

---

[5] See Proc. Roy. Soc., vol. 73, 1904. The experiment consisted in rotating a hollow cylinder or tube of ebonite about its axis, the rotation being performed in a magnetic field the direction of which coincided with the axis of rotation. The inner and the outer cylindrical surfaces were each covered with a metallic film, against each of which sliding brushes made contact. The brushes were connected to a quadrant electrometer the deflection of the latter thus becoming a measure of the charge displaced through the walls of the cylinder.

The results indicated that an electromotive force was produced between the inner and the outer conducting cylindrical surfaces the same as though a conductor had been used instead of ebonite, but that the value of the electromotive force was less for the ebonite in the ratio of $\frac{K - K_0}{K}$; K being the electric permitivity of the ebonite and K_0 that of free ether, that is numerically $K_0 = 1$ when $K =$ the specific inductive capacity of the moving dielectric (in this case ebonite).

See also Blondlot, *Journal de Physique*, January 1902.

Dr. Steinmetz's description of why a magnetic field remains fixed in space while the magnet generating it revolves on its axis is interesting. It seems, however, that high authorities differ on this point,* hence, the question must still be considered an open one.

I am pleased to see that Dr. Kennelly agrees with me that the movement of magnetic flux across the boundary is the primeordial proposition and the increase or diminution of flux in a loop is secondary. This statement is merely another way of saying that Faraday's statement of the law is the fundamental one and explains the seat of the induction, while Maxwell's statement is a deduction from it, applying only to special cases with strict limitations (which latter do not generally accompany the law in text-books).

One of Professor Elihu Thomson's remarks, namely, that he formerly used Maxwell's law, but later adopted Faraday's view of line cutting as the essential thing, bears out the contention that Faraday's law is the more reliable. His proposed universal law, followed afterwards by an admitted exception, illustrates the difficulty of framing a universal law.

Dr. Franklin's remarks show that the teacher who looks at these phenomena in a broad and general way will be apt to supply in his own mind the omitted limitations of a briefly stated law or rule. Students, however, as also many who are engaged in practical work, accept a law as it is stated and apply it literally; hence they may be very seriously misled unless the limitations clearly accompany such a law.

Mr. Thomas's remarks, in my opinion, illustrate very forcibly my contention that the statement of Maxwell's law is imperfect; for if it requires such a complicated interpretation as he gives in order to make it fit this experiment, and perhaps even more intricate interpretations to fit other possible cases, it certainly is not in correct form to be given to students and practicing engineers to use as it reads. A careful student reading Mr. Thomas's explanation, would naturally feel great uncertainty in applying Maxwell's statement of the law to other unusual cases before he knew the result. If, in this experiment, the continuously closed circuit must be considered as being *broken* (as Mr. Thomas states in italics), then it must necessarily follow that in all other sliding contacts, such as those on alternators, revolving fields, induction motors, etc., the circuit must be considered to be broken all the time. Hence the current is flowing through a broken circuit without causing an arc—which, of course, leads to an absurdity.

---

* See Modern Views of Electricity, Lodge, 1907, Section 73, page 142. Also A Treatise on Magnetism and Electricity, Andrew Gray, 1898. page 329, Section 423. in which the author says: " When the magnet moves, its field of force moves with it."

Replying to Mr. Graham, I need only say that the experiment deals only with permanently closed circuits through which a steady current could be flowing all the time. Hence his analogy to a circuit which is opened and the flux moved out through the opening, is not legitimate discussion of the experiment itself.

Mr. Hanchett's first experiment is essentially different from mine and has no bearing on mine as it distinctly opens and closes a circuit at a switch. His second experiment is described in my paper, Fig. 3. It seems that Mr. Hanchett has evidently failed to see the very point of the experiment, which was that in teaching students the laws and rules for their practical use, these laws and rules should be so stated that the student will readily understand them, can feel absolute reliance in them, can predict results with certainty and reliance, and will not have to resort to complicated interpretations (like leaving a part of a circuit behind notwithstanding that all of it has been visibly removed) in order to make the laws fit special cases after experimental investigation has shown what the result is.

Mr. Waring's suggestions of methods to determine whether a field moves with its magnet or not, are very ingenious, particularly the one with the water-drop collectors, which it seems to me would not be difficult to carry out. As the result is a simple question of fact concerning which the theories of able authorities give contradictory results, it would be very interesting to have this experiment carried out. I had suggested the use of condensers for such an experiment but his water-drop method would give cumulative results which makes the measurement easier. The precaution of course should be taken to stop the rotation of the magnet before connections are made with the electrometer, so that there could not be any question of a possible induction in any leads, which has heretofore been the great stumbling-block in any direct measurements.

Mr. Campbell's statement that " the current is determined by the integral electromotive force around the circuit" is, in my opinion, an evident fallacy, as every student will know that a current is not determined by the electromotive force, but by the quotient of the electromotive force and the resistance; without a knowledge of the resistance the current is a decidedly indeterminate quantity. In his paragraph 2 he virtually says that "as the current" is "invariably closed, it follows as a mathematical necessity that" there cannot be any such a thing as an open circuit, hence Maxwell's loop law is universal!

Of course if one starts out with the arbitrary assumption that an electric circuit cannot ever be opened, then one thereby incapacitates himself to even consider such a thing as induction of electromotive force in an open circuit. Persons who have been left embarrassed in the dark by an opening of the electric light-supply circuit, or whose motors have been stalled for a similar reason, will not have much faith in arguments as to the impossibility of opening circuits. If Mr. Campbell will read Faraday he will find that this distinguished experimenter invariably made experiments first and suggested theories to accord with the facts afterwards. I believe he was never guilty of torturing facts to fit premature theories; he never to my knowledge had to interpret a closed circuit to be open or an open one to be closed, in order to fit a pet theory to the facts. To Mr. Campbell's arbitrary assertion that induction "where no materials are present" is "one of the most important applications" of the law under discussion, it is I hope not necessary to reply; the usual industrial use of induction is to get useful currents, which could not flow where there are no materials to conduct and confine them. Why should we be expected to accept his very arbitrary and non-proved statement (4) that "it is self-evident that the fundamental statement of the law of induction applies to linear circuits" (presumably meaning *closed* circuits or complete loops, as he described before). Authorities, who are recognized both here and abroad, consider the general case to include all kinds of circuits whether open or closed, the closed circuit being therefore a special case; in order to be fundamental, a law must apply to the general case. Many who have been asked have acknowledged frankly, and in a true scientific spirit, that Maxwell's law as usually stated would *not* have predicted the correct results of this experiment *before the results were known*: hence Mr. Campbell's arbitrary statement that it "enables the results to be predicted in any case whatsoever" is not borne out by facts. That the experiment "throws no new light on the subject" is a matter about which others have expressed a different opinion to me. One of the chief objects of my paper was to try to show that there is room for improvement in teaching students the fundamental laws, so that they will obtain such a clear and unencumbered conception of those laws that they will have confidence in applying them for predicting results, without involving complicated "interpretations"—such as having to consider an open circuit to be a closed one, or the reverse—which require an experimental determination before a correct prediction can be made. Mr. Campbell's discussion is a good illustration of this.

Mr. Thomas has claimed above that what is universally considered by electrical engineers to be a closed circuit must now be considered to be an open circuit in order to make his theory fit this case, and now Mr. Campbell claims that what would generally be considered to be an open circuit must now be considered to be a closed one in order to make his theory fit this case. I think this is a good illustration of the point raised in the paper, that Maxwell's law is not in a satisfactory form for teaching students, or for engineers to use.

DISCUSSION ON "THE EVOLUTION OF ENGINEERING." ATLANTIC CITY, N. J., JUNE 29, 1908

(*Subject to final revision for the Transactions.*)

Charles F. Scott: In the president's address reference is made to the part that the presidents of the national engineering societies played at the conference at Washington. One of the speakers referred to that conference as marking an era in American thought and American action. It seems to me it also may mark an era in the position the national engineering societies are to take as to public matters in general.

As a society, and as engineers, we may well congratulate ourselves on the part our president took in formulating the resolutions which were the formal outcome of that great and notable conference. It has been the ideal of many of us that the engineers of America, through their engineering societies, might get together for concerted action such as this. That was one of the ideas underlying the project in the Engineers' Building, and it is a happy outcome that so soon after it was opened, the founder societies should have taken such an important part in this great national work.

The president's address admirably indicates the position which engineers should take in the future with regard to matters of this sort. The other papers this morning have been along the same lines, calling for the highest action, the coöperation of engineers, on larger scale and in larger matters, and we can also congratulate ourselves that the new president, in sounding his keynote, has looked also to the broader and more useful development of the engineering society.

DISCUSSION ON "FROM STEAM TO ELECTRICITY ON A SINGLE-TRACK ROAD." ATLANTIC CITY, N. J., JULY 1, 1908

(Subject to final revision for the Transactions.)

J. B. Whitehead: This paper was suggested by some of the questions arising in undertaking to change a 30-mile, single-track road from steam to electricity. It is understood, of course, that every project of this nature must be considered in the light of the particular conditions involved, so that it is rather to the methods which have been followed in the present case than to the actual results and values which were finally adopted, that I ask attention.

W. I. Slichter: In the equipment of a single-phase railway system one of the most important points is the design of the conductor system, since there is not the synchronous converter to fall back upon as a booster to make up for any line losses by its compounding.

The drop in voltage in the rails with alternating current has been investigated by various persons, but as Mr. Whitehead has pointed out, there seems to be considerable difference in the results obtained. It is probable that these results differ because of the numerous conditions which enter with important effects into the phenomenon.

The drop in the rail varies with the perimeter of the rail, because it is a skin effect; it also varies with the chemical composition of the rail, which affects the permeability; with the bonding which affects the true or ohmic resistance of the circuit, and with the quantity of current in the rail, as this affects the permeability; and with the leakage of current to ground.

While the results of experimental tests will differ greatly on this account, conditions found in practice do not vary so greatly and we do get quite reliable and uniform values.

The general results of a series of tests made under operating conditions show that at 25 cycles the impedance drop in the rail itself is approximately eight times as great as the ohmic drop with direct current, that the power-factor of this drop is about 80 per cent. The impedance drop in the trolley is approximately 50 per cent greater than that with direct current. The result is that the total drop with alternating current is approximately twice as great per ampere as the drop with direct current.

An interesting feature of this voltage drop is that it has a power-factor of a value somewhere between the power-factor of the input to the car at free running and at starting, but more closely approximating the power-factor of free running. Thus under free-running conditions this drop is almost algebraically subtracted from the sub-station voltage.

At starting, when the input to the car has a value about twice that of free running, the drop is out of phase with the line voltage and is subtracted geometrically at a large angle, so that at starting there is a loss of voltage only about 50 per cent greater than that at free running, although the ratio of line current and actual voltage drops is as two to one.

Wm. McClellan: In regard to the choice of systems. Of the various systems proposed for electrification, none of us knows which one is going to be the best, if there is a best. I am perfectly willing to grant that there may be a heavy grade at some place where a 1200-volt, direct-current system may seem the best; there may be a long grade, perhaps, where a three-phase system may seem very advantageous; there are other places where the 11,000-volt, single-phase system may seem the right one; and still other places where the 650-volt system may seem best; and so on.

But we are not electrifying heavy grades or tunnels. We are not electrifying small portions of systems. We are beginning to electrify whole systems. Therefore, while we cannot at present choose any one system and electrify by means of that system, yet we must constantly realize that the great problem we have is the electrification of the large system. If we are called upon to work with a tunnel or grade, or something which needs immediate electrification, let us keep in mind the whole problem of the general electrification of the whole road at some future day.

I know of one place where they want to make a forty-mile extension on a part of the system, where a certain system of electrification is used on the original part of the road. There is no question whatever that another system of electric propulsion is most advisable for the extension; the problem is to know what to do, whether to throw away the part now in use, and remake it, or go ahead with the old system and install that on the extension, which is the easiest thing to do, and trust to the future.

It is fortunate that one large system decided to solve their problem on a general basis. As a result they have been subjected to criticism, because some one can show where a few dollars might have been saved now by adopting some other system. They have done wisely, however, in keeping in mind the electrification of the whole system rather than to adopt the method that is perhaps more immediately applicable.

A. H. Babcock: The method given herein is not the only accepted one to be followed in discussing problems of this character. If it were the only method, in at least one case with which I have to deal, we would be hopelessly at sea. That particular case involves the electrification of about 135 miles of trans-continental railroad over the Sierra Nevadas, with a grade rising 7,000 ft. in 83 miles.

Have there been any tests made on the road, as in operation, to show how much drop was encountered in the rails and in the overhead system, as compared with the calculated figures?

J. B. Whitehead: There have been no tests of these figures. The best I was able to do was to take the literature as I found it in the matter and lay the system out. The starting conditions are excellent, so far as I can observe. As for actual figures of drop, I have not been able to get any.

A. W. Copley (by letter): The subject of the constants of alternating-current railway circuits is one to which I have given considerable attention. During the last few years I have had opportunity to make a number of tests for the determination of such constants, the most important of which were made on the New York, New Haven & Hartford Railroad, under the general direction of C. F. Scott and W. S. Murray. The data obtained in these tests are summarized in the following tables. The values given for double track and single track are calculated from the data obtained on the four track road; the values obtained in this manner for single track check closely with the results of tests made elsewhere on single track roads.

The impedances given in the table are the electromotive forces required for sending current through the circuit and are practically equal to the difference between the electromotive forces at the power house and that at the load. The values in the table are the volts required per mile per hundred amperes in the trolley.

The figures showing the division of current between the track and the earth refer to intermediate portions of long sections; the division is different near the power house and near the load.

The figures in the tables apply to average practical conditions and are suitable for the calculation of commercial circuits.

FOUR-TRACK ROAD

Four 0000 trolley wires........ Eight 100-lb. rails.

Electromotive force	25 cycles	15 cycles
Resistance		
Trolley	6.8 volts	6.7 volts
Rail	1.8 “	1.5 “
Total	8.6 “	8.2 “
Reactance		
Trolley wires (internal)	0.35	0.2
Rails (internal)	0.85	0.5
Between trolley and return circuit	15.6	9.4
Total	16.8	10.1
Impedance, total	18.9	13.
Division of current		
Each outside trolley wire	26.6 amperes	26.3 amperes
Each inside trolley wire	23.4 “	23.7 “
Rails	75 “	
Earth	25 “	

FOUR TRACK WITH AUXILIARY FEEDERS

Four 0000 trolley wires	Two 00 feeders	Eight 100-lb. rails
Electromotive force	25 cycles	15 cycles
Resistance		
Overhead wires	5.7 volts	5.6 volts
Rail	1.8 “	1.5 “
Total	7.5 “	7.1 “

Reactance		
Overhead wires (internal)	0.2	0.1
Rails (internal)	0.9	0.6
Between overhead wires and return circuit	13.3	8.0
Total	14.4 volts	8.7 volts
Impedance, total	16.5 "	11.2 "
Division of current		
Each feeder wire	14.2 amperes	
Each outside trolley	18.8 "	
Each inside trolley	17. "	
Rails	75 "	
Earth	25 "	

Double-Track Road

Two 0000 trolley wires	Four 100-lb. rails	
Electromotive force	25 cycles	15 cycles
Resistance		
Trolley	13 volts	13 volts
Rail	2.5 "	2 "
Total	15.5 "	15 "
Reactance		
Trolley wires (internal)	0.6	0.4
Rails (internal)	1.2	0.7
Between trolley wires and return circuit	25.1	15
Total	26.9	16.1
Impedance, total	31.	22.
Division of current		
Rails	58 amperes	
Earth	42 "	

Single-Track Road

One 0000 trolley wire	Two 100-lb. rails	
Electromotive force	25 cycles	15 cycles
Resistance		
Trolley	26 volts	26 volts
Rail	3 "	2 "
Total	29 "	28 "
Reactance		
Trolley wire (internal)	1.3 volts	.8 volts
Rails (internal)	1.5 "	.9 "
Between trolley and return circuit	44.2 "	26.5 "
Total	47. "	28.2 "
Impedance, total	55.3 "	39.6 "
Division of current		
Rails	40 amperes	
Earth	60 "	

Note.—With 000 trolley wire instead of 0000 for single track the total impedance in volts per 100 amperes per mile is 60.

The earth losses are left out of the above tables. Such losses are comparatively small and are not easily measured; moreover they undoubtedly vary greatly with different kinds of soil and the ballast of the roadbed, the largest part of the loss occurring in the region where the current is leaking the rails and going into the earth.

Mr. Whitehead has given figures for various losses in railway circuits published by Parshall & Hobart and by the Railway Test Commission and has made calculations of such constants from theoretical considerations. A comparison of the values given in his paper with values obtained from the tests on the New Haven road brings out several interesting points.

Rail impedance. The values for the ratio between the impedance of the rails at 25 cycles and the direct-current resistance, are given from Parshall & Hobart as 8.1 and from the Test Commission Report as 5.5. These ratios are presumably for an 80-lb. rail. Measurements made on the New York, New Haven & Hartford Railroad with 100-lb. rails with 0000 bonds gave a value of between 2.5 and 3 for the ratio. This ratio was obtained with current densities of from 40 to 200 amperes per rail, and the results show only a very slight increase in the ratio with increased density. The resistance of the rail showed no noticeable change with the density, but the impedance rose slightly as the density increased.

Rail resistance. The resistance of the rails to alternating current at 25 cycles as measured on the New Haven road was 0.16 ohm per mile of single rails. Multiplying this by the rail current gives the ohmic drop of voltage in the rails. With 100 amperes per rail, this would amount to 16 volts. This value is little more than half of the value given by the Railway Test Commission (28.8 volts for 80-lb. rail) which is used in Mr. Whitehead's calculations.

Rail reactance. The reactance volts within the rail was found in the New Haven tests to be about 8 volts per 100 amperes per mile for a single rail. The value used by Mr. Whitehead (21 volts for 80-lb. rail) in his calculations is that taken from the Railway Test Commission's tests and is over double the value given above for a 100-lb. rail.

Rail current. The proportion of the trolley current which returns by rails is seen from the tables to vary according to the number of tracks. A single-track road has only 40 per cent of the current returning by the rails while a four-track road has 75 per cent.

At the point where current enters the rails on a single-track road 70 per cent of the current starts toward the power house and 30 per cent in the opposite direction. The 30 per cent leaks from the rails into the earth in from two to three miles. Coming toward the power house the 70 per cent decreases to 40 per cent in about the same distance, and the rail current then stays at this value until near the power house. Similar results were found on the four-track road, 87 per cent starting toward the power house and decreasing to 75 per cent in two miles.

Position of earth current. The position of the earth current varies, no doubt, under different conditions of soil etc. On the New Haven road it was found that if the earth conductor was assumed as 1000 ft. in diameter and tangent to the surface at the rails, the constants of the circuit calculated theoretically would be substantially the same as those determined experimentally. For a single-track road an assumed diameter of 600 ft. gave theoretical constants the same as the measured values.

Impedance volts due to trolley current. In the calculation given for the division of current between a 000 copper trolley wire and a $\frac{7}{16}$ in. steel messenger wire, it does not appear that any allowance has been made in the value of R_1 (the resistance of the messenger wire) for the fact that the current is alternating. The value 3.7 ohms is about the value of the resistance to direct current, but 9 or 10 ohms is probably nearer the value for the resistance at 25 cycles. By making this change from 3.7 to 10, the values of i_2 and i_1 (the currents in the trolley wire and messenger respectively) become 97 and 3.5 amperes, respectively and E (the impedance voltage in the circuit due to the trolley current) becomes 47.2 instead of 44.75. This value of E (47.2 volts) is close to the value found by neglecting the messenger wire as a conductor.

Impedance volts due to rail current. The resistance volts due to rail current as given above is 16.2 per 100 amperes in each rail per mile of 8.1 volts per 100 amperes in a pair of rails per mile.

The reactance volts due to the field inside the rails is 4 volts per mile of single track (two rails). The reactance volts in the trolley-rail circuit due to rail current is calculated from the distance between rails and trolley wire, the rail current, and the diameter of the rails. If this last is taken as 2.5 in., the value of reactance volts is about 32 as is given by Mr. Whitehead for 100 amperes in each rail or 16 for 100 amperes in the track. The total impedance due to track current of 100 amperes is then $8.1 - j\,20$. Adding this to the value deduced for the impedance due to the trolley current, gives E_0, the total impedance, as 67.8 volts per mile per 100 amperes for 000 trolley wire and 100 lb. rails. Taking into account that the rail current is only 40 per cent of the trolley current drops the value of E_0 to about 60 volts.

Chas. F. Scott: Mr. Copley is, I believe, substantially correct in his measurements, and what he has contributed is a valuable addition to our knowledge on this subject. I might add that the height of the trolley wire is 22 ft.

J. B. Whitehead: I am particularly glad to see these figures. This is one of the objects which I had in mind in bringing the calculation of the impedance volts into the paper. I have only seen Mr. Copley's figures for the first time, in the last few minutes, and am not prepared to make specific comments upon them.

The value of the impedance volts for the single-track road is what I was most concerned with in my paper. I notice that the total impedance in Mr. Copley's discussion at 100 amperes per mile, is 60 volts as against 65 volts given in my paper.

The difference between 80 and 100 lb. rails at 100 amperes per mile is appreciable; maybe it will make up for the difference in impedance values.

I did not mention the matter of rail impedance at the time I was abstracting the paper, but I called attention at the time to the difference in the ratios of impedance of rails and direct current resistances, as given by the several authorities which I quoted. I brought out in the substance of the paper the point which Mr. Copley has reported here. He has touched on the subject of rail resistance, and I would be glad to see more figures on that particular point. They are all over the place, if one looks up the measurements which have been taken, and doubtless the variations are caused by the different conditions of track under which the measurements are taken; that is the only way I can account for them.

As to the matter of rail current, these are the first figures I have seen bearing on the subject. I should like to ask Mr. Scott whether there were any single-track measurements taken at the time of these tests? Do I understand these figures for single track are calculated from the results of four track tests?

Chas. F. Scott: Yes; calculated, and also the result of direct measurement. The figures relating to three single track measurements taken at three places are from actual tests.

J. B. Whitehead: I should like to see the record of these single-track tests, because there are remarkably few at present available in the literature. The resistance of the catenary cable at 25 cycles is placed here at from 9 to 10 ohms, but by conjecture only. The value appears excessive.

S. H. Clarkson: In figuring out the cost per car-mile, I should like to know whether Mr. Whitehead took the locomotive into consideration, and if so to what extent? It seems to me that the cost per ton-mile would be a much more equitable basis for comparison, not only in the present instance where a steam and a single-phase road are being considered, but in all cases where it may be necessary to compare trains having different equipment or motive power.

J. B. Whitehead: I shall answer the question last asked. The figures given at the end of the paper on the relative costs of operation are based entirely on the passenger traffic of the road. The freight traffic will be handled by steam, certainly for the present. The comparison here given is entirely on the basis of passenger traffic, and it has been estimated that a certain car mileage was necessary to handle the passenger traffic. That is the reason for the basis of car-mileage.

As to the maintenance of locomotives, the figures for the cost of maintenance are at once available from the company's books, and it was a simple matter to put them on the car-mileage basis.

DISCUSSION ON "WORKING RESULTS FROM GAS-ELECTRIC POWER PLANT. REPORT OF 30-DAY TEST ON SERVICE PLANT, RICHMOND WORKS, AMERICAN LOCOMOTIVE COMPANY," ATLANTIC CITY, N. J., JULY 1, 1908

(Subject to final revision for the Transactions.)

J. P. Jackson: I have found, as I presume all who have dealt with gas power-plants have found, that the first question to be determined is that of reliability. Is it possible to have a plant that will operate continuously with good service under all conditions, a plant that will not shut down on account of trouble of one kind or another, as gas plants have a habit of doing?

The first cost of gas plants has been referred to, and it is admittedly high. A steam plant can usually carry a heavy overload but it is difficult to equal such service with a gas plant unless the gas is exceedingly rich. If the gas is poor even less than rated load is sometimes obtained.

Flexibility and reliability of the auxiliaries is essential. Can a spark system be made reliable? A system that can be fixed, in case it gets out of order, without shutting down the whole unit? Probably, with proper duplication, that can be done. Compressed air is usually used to start gas engines. I think many gas plants have had trouble because the compressed air apparatus has not been independent, so that in case the air is lost in the tanks, they can be pumped full in a few minutes. Circulating pumps and coolers are needed, unless water is inexpensive. Such water is for cooling the engines and for use in the scrubbers and vaporizers. If a suction producer plant is under consideration, a blower is necessary to start the fire and also suitable arrangements must be made for cleaning fires, if it is desired to run twenty-four hours a day.

So far as I am able to observe, if a small gas plant is in good running order the labor is less expensive than in the case of steam plants, though in most cases such plants being still in the experimental stage, there is apt to be extra expense which materially raises the labor account. I believe, however, that when we get the gas engine to the same point of perfection, the labor will probably be a less expensive item than in the case of the steam plant. In a plant with a large load-factor the fuel cost will be less than that in a steam plant of small unit or size. The saving in coal has to be offset against other items, however. The cost of water is important, inasmuch as a water cooler and condenser must be used.

Deterioration and repairs have been enormous items of expense, which can be eliminated to a large extent. There is no reason why a well-designed gas engine cannot maintain its brasses, instead of having them eaten out by sulphuric acid; why it cannot continue to run with about the same stability as a steam engine.

So far as making the gas goes, producers for gas purposes are undoubtedly less expensive to keep up, and they need less attention than steam boilers. They cost less originally. In gas plants there are needed gas testers that continuously record the character of the gas, these are as necessary as gauges in a steam plant to record the steam pressure. Suction gauges are scarcely sufficient.

I have spoken of troubles, because they have come forcibly to my notice. But I believe that so far as reliability of service goes, it should be possible to build a producer plant which will give just as reliable service as a steam plant, especially for small units in locations where the price of fuel is high. The annual cost, including depreciation on the higher first cost, labor, and fuel, and every other item of expense, should be in many cases less for the gas plant than for the steam plant.

J. R. Bibbins: The ability of a gas-power plant to carry overload is entirely a question for the designing engineer to decide. The maximum capacity of a gas engine is reached when the cylinder is full of mixture of maximum density; this is analogous to a steam engine taking full-stroke steam. At the present time engines of good construction are rated with a continuous overload capacity of from 10 to 15 per cent. In the plant at Richmond the engine has sustained a one-hour overload of over 30 per cent, or a three-hour overload of 19 per cent. These results were obtained with good gas, but conditions are not always so favorable, and conservative builders lower their ratings in order to cover contingencies entirely beyond their control. In fact this particular engine has about 20 per cent excess capacity. A knowledge of future operating conditions would undoubtedly have enabled the designer of this plant to take advantage of this in electrical ratings.

The steam turbine, as built to-day in America, is exerting an embarrassing influence on the question of gas-power ratings, as American practice is extremely conservative. Compared with German practice, for example, it will be found that foreigners are much less conservative in overload ratings, as determined by temperature guarantees. If the same basis of rating existed for domestic machinery as for foreign generating machinery, even turbines, American practice in gas-engine ratings would not be so generally criticized, and the prime mover would not be called upon to compensate for deficiencies in plant equipment or operation. Standardization of gas-power practice is now being considered by the American Society of Mechanical Engineers. A committee was appointed last December, and within the next year it is probable that American practice will be well defined and placed upon a more logical basis than at present exists, where nearly every manufacturer has his own standards.

The principal object of the paper is to present some definite data on the operation of the modern plant properly equipped and operated, data which clearly refute the general charge of unreliability and costliness so often encountered. Such charges are usually based upon individual experience or general misinformation. There is nothing unusual about the Richmond installation—a standard type of gas engine—a simple form of bituminous producer with independent auxiliaries for tar removal. The plant is capable of continuous operation through the use of water-seals at the producers; the lubrication and cooling of the engine are automatic; the ignition system is in duplicate; and the governing fully as sensitive as in standard steam practice—2 to 2.5 per cent variation of mean speed. Although a direct-current installation in this instance, the regulation obtained from this type of engine is sufficient to permit alternating current parallel operation without the use of spring couplings.

DISCUSSION ON "THREE-PHASE POWER-FACTOR." ATLANTIC CITY, N. J., JUNE 30, 1908

(*Subject to final revision for the Transactions.*)

Comfort A. Adams: I think that at least a part of Mr. Burt's demonstration may be rendered less mathematical to the advantage of one's physical conception of the problem. I refer to that part leading up to equation (34) which is the algebraic statement of the validity of the ordinary method of measuring three-phase power by means of two wattmeters.

Since in any three-wire system the algebraic sum at any instant of the three currents counted positive in the same direction along the circuit is zero, one of these currents may be legitimately looked upon as the common return for the other two, since when counted positive backwards it is equal at each instant to the algebraic sum of the other two currents counted positive outwards. Any three-wire three-phase system may then be considered as a three-wire two-phase system.

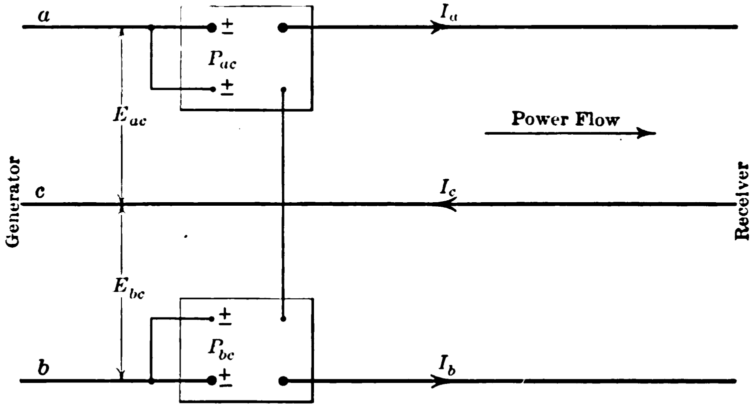


FIG. 1

In Fig. 1, c is taken as the common return and the total power at any instant is, $p = e_{ac}i_a + e_{bc}i_b = p_{ac} + p_{bc}$. The small letters indicate instantaneous values, the order of voltage subscripts indicates the direction in which the voltage is counted positive, and the arrows the directions in which the currents are counted positive.

What is true of the instantaneous values of the powers is true of their average values and of the readings of the wattmeters; or using Mr. Burt's notation, $P = P_{ac} + P_{bc}$. No assumption is here made as to the shape of the electromotive force or current waves. If the power flow is from left to right in both circuits, both wattmeters will give positive deflections when connected as shown. If one gives a negative deflection when so connected, it indicates a backward flow of power in that circuit and the reading of this instrument, when its pressure-coil connections have been reversed, must be subtracted from that of the other wattmeter to give the total outward flow of power.

Thus the point of view involved in this proof (if it may be dignified by that name) not only emphasizes the direction of power flow and its relation to the relative direction of current and electromotive force, but it also points out a positive method of connecting the two wattmeters into the circuit.

The proof given above is only a special statement of the more general proposition* that if in any three-wire system, (Fig. 1), the currents i_a and i_b and the simultaneous electromotive forces e_{ac} and e_{bc} are given for any instant, the system is for that instant completely determined in all its vital aspects, and that it is entirely immaterial as to how the three wires may be interconnected in the receiving apparatus, which may be two-phase, single-phase, three-phase star, three-phase delta, or a complicated network of many branches.

There should therefore be a power-factor so defineable that it is wholly determined by E_{ac}, E_{bc}, I_a, I_b and their phase relations, and thus independent of the number of branches of the receiving circuit. Of such a power-factor Mr. Burt has very opportunely supplied the definition.

The proposition given above, as well as Mr. Burt's definition of power-factor, apply equally well to an n wire system of which $n - 1$ line currents and $n - 1$ line voltages are given.†

Frederick Bedell: As I understand Professor Adams, the explanation he has given can be made to form a rigorous proof if it is expressed in mathematical language by the method given by Professor Blondel in his paper on "Measurements of the Energy of Polyphase Currents" in the *Proceedings of the International Electrical Congress of* 1893.

H. L. Wallau: The method of measuring the power-factor of an unbalanced delta system appeals to me because in our system we use exclusively a three-phase delta, 2300-volt distribution. The main power feeders are separate three-phase feeders and are, generally speaking, balanced. However, our lighting circuits also have small amounts of power connected to them, a great many having single-phase loads in the form of small motors, mercury rectifiers, and arc lamps, together with single-phase branches supplying straight incandescent loads. For that reason our lines are to a greater or less extent unbalanced, and it has been of a great deal of importance to us to obtain an average power-factor which would truly represent the conditions on any particular feeder.

---

* At the time of the oral discussion of this subject at Atlantic City the writer was convinced and stated that the proposition given above covered also the proof leading up to Mr. Burt's equation (35), but while the conviction remains, he has been unable to see the connection clearly enough from the physical point of view to express it in simple non-mathematical form.

† "Polyphase Power Measurement" by C. A. Adams, Electrical World Jan. 19, 1907, p 143.

I think that in all cases where similar systems are being used, the power-factor on the system, as a whole, can be closely approximated by obtaining power-factor on various feeders. I have used various approximations to get at the average power-factor on the sub-station, for the purpose of determining the proper size of rotary condenser to be installed, to bring the power-factor up to such a value as would give an economical transmission from the generator to the sub-station, and also under certain cases the proper size of condenser to be installed on the customers' premises, in order to bring the power factor up, sometimes, from a value as low as fifty per cent, to what might be called a livable value, one commercially practicable.

B. A. Behrend: I think that Messrs. Adams and Bedell are correct in regard to their simple way of proving the time-honored method of measuring the power-factor and the kilowatts of a three-phase alternating-current circuit. Their method is very interesting and instructive.

General Electric Company

Aluminum Cell Lightning Arresters

For the protection of alternating current systems

View of parts of one leg of 12,500 volt
Aluminum Cell Arrester

Operation of arrester depends on a film formed by electrolytic action on the surfaces of a series of aluminum cones.

**Some Exclusive Advantages of
General Electric Aluminum Cell Arresters**

The cells or aluminum cones are so shaped and supported that there is no chance of short circuiting from contact.

The strong steel tank maintains protection from external injury.

The inverted conical form of cell prevents accumulation of gases on the film surfaces and insures safe and efficient discharge.

Oil immersion of cones affords highest insulation.

Heaviest induced stroke can be discharged without causing abnormal voltage rise in system.

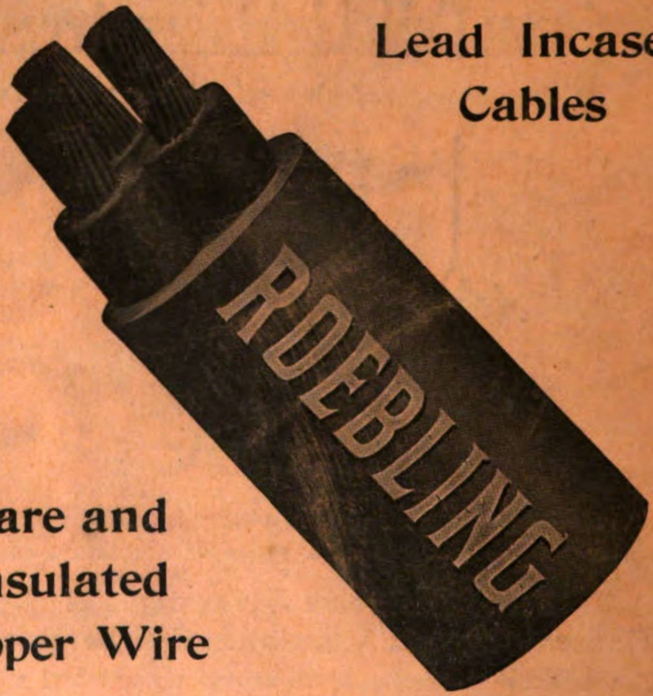
Great heat absorbing capacity of oil permits arrester to discharge continuously for half-hour without injury from high temperatures.

No dynamic current can flow as result of discharge.

Aluminum cell arresters can be supplied for operation on circuits of from 5,000 to 100,000 volts

PRINCIPAL OFFICE: SCHENECTADY, N. Y.
New York Office: 30 Church St.
Sales offices in all large cities. 1723

Lead Incased
Cables



Bare and
Insulated
Copper Wire

WIRE ROPE FOR ALL PURPOSES

John A. Roebling's Sons Co.,

Main Office and Works: TRENTON, N. J.

AGENCIES AND BRANCHES:

New York Chicago San Francisco Cleveland
Philadelphia Atlanta Seattle Los Angeles Portland, Ore.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers

Volume XXVII
Number 7

July, 1908

Per Copy, 50c.
Per Year, $5.00.

CONTENTS

Section I. Notes and Comments

Resolutions in honor of William Arnold Anthony
Frontispiece. William Arnold Anthony
Editorial Comment - - - - - - - - - - 1
Twenty-fifth Annual Convention, Atlantic City, June 29-July 2, 1908 2
Report of Committee of Tellers on Election of Officers - - 5
Sections and Branches - - - - - - - 6
Associates Elected and Transferred June 12, 1908 - - - 8
Application for Election - - - - - - 13
Personal - - - - - - - - 14
Obituary - - - - - - - - 15
Accessions to the Library - - - - - - 16

Section II. Papers, Discussions, and Reports

(Atlantic City Convention June 29-July 2, 1908.)

The General Equations of the Electric Circuit, by C. P. Steinmetz 1121
Notes on the Electric Heating Plant of the Biltmore Estate, by Charles E. Waddell - - - - - 1197
Relation of the Manufacturing Company to the Technical Graduate, by David B. Rushmore - - - 1213
Water Power Development in the National Forests. A Suggested Government Policy, by Frank G. Baum - - - 1217
Critical Study of Lightning Records on Taylor's Falls Transmission Line, by Percy H. Thomas - - - - 1227
Double-Deck Steam Turbine Power Plants, by J. R. Bibbins - 1251
Working Results from Gas Electric Power Plants, by J. R. Bibbins 1271
Wireless Telephony, by R. A. Fessenden - - - 1283
Discussion (by letter) on Convention Papers - - - 1359

Report of Board of Directors for Fiscal Year Ending April 30, 1908 1371
Report of Library Committee for Year Ending April 30, 1908 - 1383
Index to Advertisements - - - - - - - ii

Copyrighted 1908, by the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. Permission is given to reprint any matter provided proper credit is given.

Entered as matter of the second class at the post-office, New York, N.Y., December 17 1904, under the Act of Congress, March 3, 1899.

MAY 1909

FOUR IMPORTANT ELECTRICAL BOOKS

8 vo. Cloth. 188 pp. 163 Illus. $2.00 Net

ELECTRIC ARC LAMPS

Their Principles, Construction and Working

By J. ZEIDLER, E.E. and J. LUSTGARTEN, M. Sc.

CONTENTS.

General Remarks. Introduction. Differences of Construction. Series Arc Lamps. Shunt Arc Lamps. Differential Arc Lamps. Lamps with Open Arcs and Co-Axial Vertical Carbons. Flame Arc Lamps. Enclosed Arc Lamps. Light Intensity and Light Distribution. Illumination. External Connections. Accessories for External Connections. Table of Photometric Quantities. Table of Comparative Costs of Usual Sources of Light. Standardization Rules on Photometry and Lamps of the American Institute of Electrical Engineers.

8 vo. Cloth. 293 pp. 67 Illus. $2.00 Net

ELECTRIC POWER and TRACTION

By F. H. Davies.

CONTENTS.

Introduction. The Generation and Distribution of Power. The Electric Motor. The Application of Electric Power. Electric Power in Collieries. Electric Power in Engineering Workshops. Electric Power in Textile Factories. Electric Power in the Printing Trade. Electric Power at Sea. Electric Power on Canals. Electric Traction. The Overhead System and Track Work. The Conduit System. The Surface Contact System. Car Building and Equipment. Electric Railways. Glossary. Index.

8 vo. Cloth. 217 pp. 38 Illus. $2.50 Net

Elements of Electric Traction

By L. W. Gant.

CONTENTS.

Introduction. Principles of Magnetism. Principles of Electricity. Principle of the Dynamo. Principle of the Continuous-Current Motor Power and Power Measurement. Mechanics of Traction. Characteristics Properties of Continuous-Current Motors. Application of Motors to Traction. Brakes. Index.

8 vo. Cloth 218 pp. 108 Illus. $2.00 Net

Laboratory Work in Electrical Engineering

(PRELIMINARY GRADE)

By JOHN ROBERTS, Jr.

CONTENTS.

The Graphical Representation of Experimental Results. Section O.—Verification of Ohm's Law. Section R.—Measurement of Resistance. Section E.—Measurement of E.M.F. Section C.—Measurement of Current. Section P.—The Potentiometer. Section K.—Calibration of Electrical Measuring Instruments. Section M.—Miscellaneous Experiments. Appendix I. Appendix II.

D. Van Nostrand Co. 23 Murray and 27 Warren Sts. New York

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers

Volume XXVII
Number 8

August, 1908

Per Copy, 50c.
Per Year, $5.00.

CONTENTS

Section I. Notes and Comments

Frontispiece. A. I. E. E. Convention at Atlantic City
Section Papers - - - - - - - 1
Institute Publications - - - - - - 1
Twenty-fifth Annual Convention - - - - - 2
Report of the Sections Committee - - - - - 6
Presentation to the Institution of Electrical Engineers - - 10
Sections and Branches - - - - - - 13
Applications for Election - - - - - - 21
Personal - - - - - - - - 22
Marseilles Electrical Congress - - - - - 27
Accessions to the Library - - - - - - 27

Section II. Papers, Discussions, and Reports

The Evolution of Engineering, by Henry Gordon Stott, Atlantic City Convention, June 29, 1908 - - - - 1391

Conservation of Power Resources, by H. St. Clair Putnam, White House, Washington, D. C., May 13-15, 1908 - - 1397

Discussion on "The Engineer's Activity in Public Affairs—Public Utility Commissions and Franchise Valuations", New York, April 10, 1908 - - - - - 1417

Index to Advertisements - - - - - - ii

Copyrighted 1908, by the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. Permission is given to reprint any matter provided proper credit is given.

Entered as matter of the second class at the post-office, New York, N.Y., December 17, 1904, under the Act of Congress, March 3, 1899.

FOUR IMPORTANT ELECTRICAL BOOKS

8 vo. Cloth 188 pp. 163 Illus. $2.00 Net

ELECTRIC ARC LAMPS

Their Principles, Construction and Working

By J. ZEIDLER, E.E. and J. LUSTGARTEN, M. Sc.

CONTENTS.

General Remarks. Introduction. Differences of Construction. Series Arc Lamps. Shunt Arc Lamps. Differential Arc Lamps. Lamps with Open Arcs and Co-Axial Vertical Carbons. Flame Arc Lamps. Enclosed Arc Lamps. Light Intensity and Light Distribution. Illumination. External Connections. Accessories for External Connections. Table of Photometric Quantities. Table of Comparative Costs of Usual Sources of Light. Standardization Rules on Photometry and Lamps of the American Institute of Electrical Engineers.

---

8 vo. Cloth. 293 pp. 67 Illus. $2.00 Net

ELECTRIC POWER and TRACTION

By F. H. Davies.

CONTENTS.

Introduction. The Generation and Distribution of Power. The Electric Motor. The Application of Electric Power. Electric Power in Collieries. Electric Power in Engineering Workshops. Electric Power in Textile Factories. Electric Power in the Printing Trade. Electric Power at Sea. Electric Power on Canals. Electric Traction. The Overhead System and Track Work. The Conduit System. The Surface Contact System. Car Building and Equipment. Electric Railways. Glossary. Index.

---

8 vo. Cloth. 217 pp. 38 Illus. $2.50 Net

Elements of Electric Traction

By L. W. Gant.

CONTENTS.

Introduction. Principles of Magnetism. Principles of Electricity. Principle of the Dynamo. Principle of the Continuous-Current Motor Power and Power Measurement. Mechanics of Traction. Characteristics Properties of Continuous-Current Motors. Application of Motors to Traction. Brakes. Index.

---

8 vo. Cloth 218 pp. 108 Illus. $2.00 Net

Laboratory Work in Electrical Engineering

(PRELIMINARY GRADE)

By JOHN ROBERTS, Jr.

CONTENTS.

The Graphical Representation of Experimental Results. Section O.—Verification of Ohm's Law. Section R.—Measurement of Resistance. Section E.—Measurement of E.M.F. Section C.—Measurement of Current. Section P.—The Potentiometer. Section K.—Calibration of Electrical Measuring Instruments. Section M.—Miscellaneous Experiments. Appendix I. Appendix II.

D. Van Nostrand Co. 23 Murray and 27 Warren Sts. **New York**

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers

Volume XXVII
Number 9

September, 1908

Per Copy, 50c.
Per Year, $5.00.

CONTENTS

Section I. Notes and Comments

Transactions for 1907 - - - - - - 1
Institute Committees - - - - - - 1
Literary Thieves - - - - - - - 1
Applications for Election and Transfer - - - - 2
Professor Anthony at Cornell - - - - - 3
Closing Session, Atlantic City Convention - - - - 5
University Branches - - - - - - - 8
Advantages of Membership in the A. I. E. E. - - - 12
Sections and Branches - - - - - - 14
Associates Elected and Transferred, August 14, 1908 - - 15
Personal - - - - - - - - 19
Books Received - - - - - - - - 20

Section II. Papers, Discussions, and Reports

Methods for Locating Transpositions of Wires and Split Pairs in Telephone and Telegraph Cables, by Henry W. Fisher, Pittsburgh Section, October 2, 1907 - - - 1437
Calculation of the Starting Torque of Single-Phase Induction Motors with Phase-Splitting Starting Devices, by I. E. Hanssen, Pittsburgh Section, May 6, 1908 - - 1449
Discussion on "The Determination of the Economic Location of Sub-Stations in Electric Railways," Atlantic City, N. J., July 1, 1908 - - - - - - - 1452
Discussion on "Comparative Tests of Lightning Protection Devices on the Taylor's Falls Transmission System," and "Studies in Lightning Performance, Season 1907," New York, May 19, 1908 - - - - - - 1454

Index to Advertisements - - - - - - ii

Copyrighted 1908, by the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. Permission is given to reprint any matter provided proper credit is given.

Entered as matter of the second class at the post-office, New York, N.Y., December 17, 1904, under the Act of Congress, March 3, 1899.

THE NEW FOSTER

Fifth Edition, Completely Revised and Enlarged, with Four-fifths of Old Matter Replaced by New, Up-to-date Material. Pocket size, flexible leather, elaborately illustrated, with an extensive index, 1636 pp., Thumb Index, etc. Price $5.00.

ELECTRICAL
ENGINEER'S POCKETBOOK

The Most Complete Book of Its Kind Ever Published, Treating of the Latest and Best Practice in Electrical Engineering.

By HORATIO A. FOSTER

Member Am. Inst. E. E., Member Am. Soc. M. E.

(With the collaboration of eminent specialists)

CONTENTS

Symbols, Units, Instruments
Measurements
Magnetic Properties of Iron
Electro-magnets
Properties of Conductors
Relations and Dimensions of Conductors
Underground Conduit Construction
Standard Symbols
Cable Testing
Dynamos and Motors
Tests of Dynamos and Motors
The Static Transformer
Standardization Rules
Illuminating Engineering
Electric Lighting (Arc)
Electric Lighting (Incandescent)
Electric Street Railways
Electrolysis
Transmission of Power
Storage Batteries
Switchboards
Lightning Arresters
Electricity Meters
Wireless Telegraphy
Telegraphy
Telephony
Electricity in the U. S. Army
Electricity in the U. S. Navy
Resonance
Electric Automobiles
Electro-chemistry and Electro-metallurgy
X-Rays
Electric Heating, Cooking and Welding
Lightning Conductors
Mechanical Section
Index

D. Van Nostrand Company

Publishers and Booksellers

23 Murray and 27 Warren Streets, New York

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers

Volume XXVII
Number 10

October, 1908

Per Copy, 50c.
Per Year, $5.00.

CONTENTS

Section I. Notes and Comments

October Meeting of the Institute - - - - - - 1
Electric Cables - - - - - - - 2
New Home of the I. E. E. - - - - - - 5
Forestry at Biltmore - - - - - - 7
Applications for Election - - - - - - 8
Sections and Branches - - - - - - 9
Personal - - - - - - - - 10

Section II. Papers, Discussions, and Reports

High-Potential Underground Transmission, by Peter Junkersfeld and E. O. Schweitzer, New York, October 9, 1908 - 1463

Discussion at Atlantic City Convention, June 29-July 2, 1908.

"Electricity as Viewed by the Insurance Engineer. Should the A. I. E. E. Interest Itself in Fire Protection?" - - 1492
"The Measurements of Rotary Speed of Dynamo Machines by the Stroboscopic Fork." - - - - - 1493
"Water Power Development in the National Forests. A Suggested Government Policy." - - - - - 1496
"A Study of Multioffice Automatic Switchboard Telephone Systems." - - - - - - - 1514
"Engineering Features of the Southern Power Company's System." - - - - - - - 1524
"Fundamental Considerations Governing the Design of Transmission Line Structures." - - - - - - 1528
"Double-Deck Steam Turbine Power Plants." - - - 1534
"Induction Motors for Multispeed Service with Particular Reference to Cascade Operation." - - - - - 1537

Index to Advertisements - - - - - - - ii

Copyrighted 1908, by the American Institute of Electrical Engineers. Permission is given to reprint any matter provided proper credit is given.

Entered as matter of the second class at the post-office, New York, N.Y. December 17, 1904, under the Act of Congress, March 3, 1899.

THE NEW FOSTER

Fifth Edition, Completely Revised and Enlarged, with Four-fifths of Old Matter Replaced by New, Up-to-date Material. Pocket size, flexible leather, elaborately illustrated, with an extensive index, 1636 pp., Thumb Index, etc. Price $5.00.

ELECTRICAL
ENGINEER'S POCKETBOOK

The Most Complete Book of Its Kind Ever Published, Treating of the Latest and Best Practice in Electrical Engineering.

By HORATIO A. FOSTER

Member Am Inst. E E., Member Am. Soc. M. E.

(With the collaboration of eminent specialists)

CONTENTS

Symbols, Units, Instruments
Measurements
Magnetic Properties of
Electro-magnets [Iron
Properties of Conductors
Relations and Dimensions of Conductors
Underground Conduit Construction
Standard Symbols
Cable Testing
Dynamos and Motors
Tests of Dynamos and Motors
The Static Transformer
Standardization Rules
Illuminating Engineering
Electric Lighting (Arc)
Electric Lighting (Incandescent)
Electric Street Railways
Electrolysis
Transmission of Power
Storage Batteries
Switchboards
Lightning Arresters
Electricity Meters
Wireless Telegraphy
Telegraphy
Telephony
Electricity in the U. S. Army
Electricity in the U. S. Navy
Resonance
Electric Automobiles
Electro-chemistry and Electro-metallurgy
X-Rays
Electric Heating, Cooking and Welding
Lightning Conductors
Mechanical Section
Index

D. Van Nostrand Company

Publishers and Booksellers

23 Murray and 27 Warren Streets, New York

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers

JOHNS HOPKINS UNIVERSITY
NOV 13 1908
LIBRARY

Volume XXVII
Number 11

November, 1908

Per Copy, 50c.
Per Year, $5.00.

CONTENTS

Section I. Notes and Comments

November Meeting A. I. E. E. - - - - - - 1
December Meeting A. I. E. E. - - - - - - 1
Minutes of October Meeting of the Institute - - - - 1
Formal Presentation of the Scott Testimonial at Atlantic City, June 30, 1908 - - - - - - - 5
Applications for Election - - - - - - 6
Applications for Transfer - - - - - - 7
The Philadelphia Section - - - - - - 7
Sections and Branches - - - - - - 10
Personals - - - - - - - - 17
Obituary - - - - - - - - 22
Library Accessions - - - - - - - 23

Section II. Papers, Discussions, and Reports

Alternating-Current Feeder Regulators, by W. S. Moody, Toronto Section, February 20, 1908 - - - - - - 1543
Discussion on "Alternating-Current Feeder Regulators," Toronto Section, February 20, 1908 - - - - - - 1561

Discussion at Atlantic City Convention
June 29-July 2, 1908.

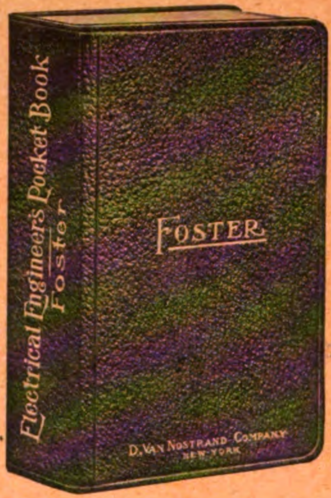
"A Trigonometric Method for the Solution of Alternating-Current Problems." - - - - - - - 1564
"Notes on the Electric Heating Plant of the Biltmore Estate." - 1567
"The Relative Proportions of Copper and Iron in Alternators." - 1569
"Primary Standard of Light." - - - - - - 1571
"Measurements of Lightning, Aluminum Lightning-Arresters, Earth Resistances, Cement Resistances, and Kindred Tests," "Tests with Arcing Grounds and Connections," "Critical Study of Lightning Records on Taylor's Falls Transmission Line." - - - - - - - - 1583
"Graphical Treatment of the Rotating Field." - - - 1606

Index to Advertisements - - - - - - - ii

Copyrighted 1908, by the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. Permission is given to reprint any matter provided proper credit is given.

Entered as matter of the second class at the post-office, New York, N.Y., December 17, 1904, under the Act of Congress, March 3, 1899.

THE NEW FOSTER



FIFTH EDITION

Completely Revised and Enlarged, with Four-fifths of Old Matter replaced by New, Up-to-date Material. Pocket-size, Flexible Leather, Elaborately Illustrated, with Extensive Index and Thumb Index.

1636 pp., $5.00 Net

Electrical Engineer's Pocketbook

The most complete book of its kind ever published
Treating of the latest and best practice in Elec. Engineering

By HORATIO A. FOSTER
Member A. I. E. E., Member Am. Soc. M. E.
(With the collaboration of eminent specialists)

CONTENTS.

Electrical Engineering Symbols.—Electrical Engineering Units.—Descriptions of Instruments.—Resistance Measurement.—Measurement of E.M.F.—Measurement of Capacity.—Measurement of Inductance.—Measurement of Power on Alternating-Current Circuits.—Tests with Voltmeter.—Determination of Magnetic Properties of Iron and Steel.—Determination of Wave Form of E.M.F. and Current.—Conductors, Properties of Conductors, Relation and Dimensions of, for Transmission of Electric Current.—Transmission of Power.—Switch-boards and Switching Devices.—Cable Testing.—Electromagnets.—Dynamos and Motors.—Static Transformers.—Electric Lighting.—Electric Railways.—Storage Batteries.—Telegraph. — Telephone. — Electro-Chemistry.—Electro-Metallurgy.—Electric Heating, Welding and Cooking.—Electricity Meters.—Lightning Arresters.—Lightning Conductors —National Code Rules and Requirements.—Miscellaneous Electrical Data.—Automobiles.—X-Rays.—Wireless Telegraphy.—Resonance.—Certain Uses of Electricity in U.S. Army and Navy.—Mechanical Section.—Index.

D. Van Nostrand Company
PUBLISHERS AND BOOKSELLERS
23 Murray and 27 Warren Street, New York

PROCEEDINGS OF THE American Institute OF Electrical Engineers

Volume XXVII
Number 12

December, 1908

Per Copy, $1.00
Per Year, $10.00

CONTENTS

Section I. Notes and Comments

December Meeting A. I. E. E., New York, December 11, 1908 - 1
Minutes of November Meeting A. I. E. E. - 2
Applications for Election - 4
Applications for Transfer - 5
Sections and Branches - 5
Personal - 16
Annual Meeting A. S. M. E., New York, December 1-4, 1908 - 18
Obituary - 19
Library Accessions - 20

Section II. Papers, Discussions, and Reports

The Log of the New Haven Electrification, by W. S. Murray, New York, December 11, 1908 - 1609

Discussion at Atlantic City Convention June 29-July 2, 1908.

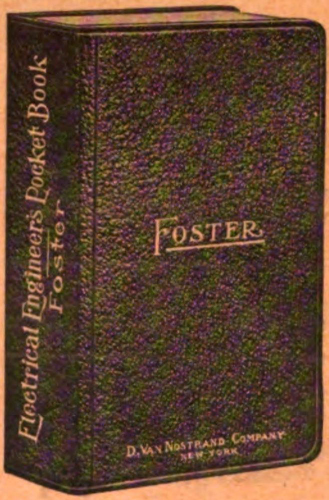
"High Voltage Experiments at Niagara" - 1661
"The Testing of High-Voltage Line Insulators" - 1687
"A New Large Generator for Niagara Falls," "Application of Fractional-Pitch Windings to Alternating-Current Generators," and "Modern Developments in Single Phase Generators" - 1694
"The General Equations of the Electric Circuit" - 1706
"An Imperfection in the Usual Statements of the Fundamental Law of Electromagnetic Induction" - 1718
"The Evolution of Engineering" - 1729
"From Steam to Electricity on a Single-Track Road" - 1730
"Working Results from Gas-Electric Power Plant" - 1737
"Three-Phase Power-Factor" - 1740

Index to Advertisements - ii

Copyrighted 1908, by the American Institute of Electrical Engineers. Permission is given to reprint any matter provided proper credit is given.

Entered as matter of the second class at the post-office, New York, N.Y., December 17, 1904, under the Act of Congress, March 3, 1899.

THE NEW FOSTER



FIFTH EDITION

Completely Revised and Enlarged, with Four-fifths of Old Matter replaced by New, Up-to-date Material. Pocket-size, Flexible Leather, Elaborately Illustrated, with Extensive Index and THUMB INDEX.

1636 pp., $5.00

Electrical Engineer's Pocketbook

The most complete book of its kind ever published
Treating of the latest and best practice in Elec. Engineering

By HORATIO A. FOSTER

Member A. I. E. E., Member Am. Soc. M. E.

(With the collaboration of eminent specialists)

CONTENTS.

Electrical Engineering Symbols.—Electrical Engineering Units.—Descriptions of Instruments.—Resistance Measurement.—Measurement of E.M.F.—Measurement of Capacity.—Measurement of Inductance.—Measurement of Power on Alternating-Current Circuits.—Tests with Voltmeter.—Determination of Magnetic Properties of Iron and Steel.—Determination of Wave Form of E.M.F. and Current.—Conductors, Properties of Conductors, Relation and Dimensions of, for Transmission of Electric Current.—Transmission of Power.—Switch-boards and Switching Devices.—Cable Testing.—Electromagnets.—Dynamos and Motors.—Static Transformers.—Electric Lighting.—Electric Railways.—Storage Batteries.—Telegraph. — Telephone. — Electro-Chemistry.—Electro-Metallurgy.—Electric Heating, Welding and Cooking.—Electricity Meters.—Lightning Arresters.—Lightning Conductors —National Code Rules and Requirements.—Miscellaneous Electrical Data.—Automobiles.—X-Rays.—Wireless Telegraphy.—Resonance.—Certain Uses of Electricity in U.S. Army and Navy.—Mechanical Section.—Index.

D. Van Nostrand Company
PUBLISHERS AND BOOKSELLERS
23 Murray and 27 Warren Street, New York

32101 048906257